VEGETABLE ORGANOGRAPHY;

OR,

AN ANALYTICAL DESCRIPTION

OF

THE ORGANS OF PLANTS.

BY

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PREFACE TO THE FRENCH EDITION.

When, after several years of observation and public instruction, I decided to publish my *Théorie Elémentaire de la Botanique*,* I wished to set forth generally the logical principles which, it appeared to me, ought to serve as the basis of the study of organized beings; and to make known, at the same time, my opinions with regard to Botany. I was well aware how much was necessary for the complete understanding of the doctrines I wished to establish, for the application of them in a more detailed manner to the different parts of the science, and especially to the description of the organs and families of plants. It is in order to attain a part of this object that I now present to naturalists a new work, which may be considered as the second part of this undertaking, viz. "Vegetable Organography; or the Analytical Description of the Organs of Plants;" which I have presented in a much abridged manner in the elementary principles which form part of the *Flore Française*, and which I have since elucidated in more than twenty public courses of lectures.

* This work was first printed at Montpellier, in 1813, and I gave a second edition at Paris in 1819; and it has been translated into German, and accompanied with Notes by M. Koemer, under the title of *Theoretische Anfrangsgrunde der Botanik;* Zurich, 2 vols. 12mo, 1814. Afterwards M. Sprengel published under the title of *A. P. De Candolle's und K. Sprengel's Grundzüge der Wissenschafftlichen Pflanzenkunde zu Vorlesungen;* 1 vol. 8vo. Leipzig, 1820;—a work, which, it is true, is an extract or translation of some parts of my *Théorie*, but which is so changed by the intermixture of other ideas, that I am obliged (seeing that the title bears my name) to declare that this work, and its English translation, are perfect strangers to me, and do not represent my opinions.

Two dangers have always appeared to me equally formidable in the study of the structure of organized beings: the one is to comprehend it *à priori* in a manner too abstract and too general, and to make it subordinate, either to analogies too distinct, or to metaphysical ideas too uncertain: it is with this that several of those may be upbraided who disdain the study of facts in order to believe the philosophy of nature. The other danger is that of only looking upon the structure of beings as isolated facts, and not endeavouring to connect them by any theory: it is with this that the simply descriptive school may be reproached.

The true way, it seems to me, lies between these two extremes; there must be here, as in all other sciences, particular facts, regulated by laws at first partial, which gradually become more general, and will one day perhaps be universal. We may thus ascend, by the successive arrangement of facts, even to theories, some of which may have been conceived by philosophers, but had not as yet been supported by sufficient proofs; exactly as from the knowledge of the laws of organization, we may descend to the examination of facts which had been seen by observers, but the connexions of which were not understood. I even doubt that any one can form any correct theories, if he have not been brought up habitually to the study of facts; or that he can make completely useful descriptions, if he have neglected entirely the theories which those descriptions ought to elucidate.

When we compare, in this point of view, the two great schools I have just mentioned, we see with surprise that the first is devoted to the study of the connexions of the structure of organs, and that it almost entirely neglects the relations of comparison derived from the collection of beings; while the second, entirely occupied with the study of those connexions, has often neglected the relations of organs, which ought to have been the basis of its labours. Several German naturalists, at the head of whom must be mentioned, in former times, the botanist Jungius, and, among the moderns, the illustrious poet Goethe, have called attention to the symmetry of the composition of plants.

Several French ones, following the example of Jussieu and Adanson, have searched into the simple intuitive knowledge of beings to establish natural groups or families of plants.

It seems that the former have given all their attention to compare together the parts of the same being; and the latter, to compare the analogous ones of different beings.

As for me, I am persuaded that these two branches of the science are inseparable; and my *Théorie Elémentaire* had for its object to connect them, by making each of them serve for the perfecting of the other. Since then I have expressed the hope of showing their connexion in a more intimate manner, by publishing the elements of each of them. The Organography is the development of that which relates to the symmetry of partial organs; and the *Prodromus* is intended to indicate the summary of the actual state of our knowledge of the affinities of the whole which constitute the natural families.

The state of families being subordinate to the continual discovery of new plants, and to the more attentive observation of those which are the least known, is necessarily provisional in several points. The general ideas of organography are also subordinate to the same courses, and will, without doubt, be gradually ameliorated. But we may know, in these two studies, if we follow a good or bad course, when we see if the exceptions have a tendency to be classed under the established laws, or whether they require to be admitted into new ones. For, in proportion as my observations are multiplied, as they have been increased by the labours of the most skilful botanists of the present day, as analogous labours have been published upon the animal kingdom, I have successively seen most of the facts which it would appear inconsistent to class in the doctrines which I have proposed; I have seen disappear, by a better observation, the anomalies to which, for reasons of prudence, I gave some weight; I have seen most of those who began by opposing my opinions, finish by admitting them, although frequently with different terms, and some of them without mentioning their origin; and I have been led to believe that the time elapsed since the publication of the *Théorie Elémentaire*, has been usefully employed in the discovery of the truth. During this interval, a great number of facts, or opinions, which I have either pointed out by some words in the *Théorie Elémentaire*, or reserved for the Organography, have been observed and published by others; but far from having regret, I have thought with pleasure that these facts, divested of all theoretical idea, may be admitted with more confidence by those who would be alarmed at new theories,—as if to reject them was different from retaining an old one, most frequently admitted without examination.

Organography is the common basis of all the parts of the science of organized beings: considered with regard to what relates to the symmetry of beings, it is the foundation of all the theory of classifications; with regard to the use of organs, it is the base of physiology; with regard to the exact description of these organs, it is the principle of glossology and descriptive natural history. If I only published it after my *Théorie Elémentaire*, it is because it is itself subservient to the general reasoning of the science which I have endeavoured to elucidate; but it is probable that beginners will find the advantage of first reading the Organography, in order to pass on afterwards to the other branches.

An elementary work of this kind must necessarily contain a great number of facts already known; but perhaps botanists will find some interest in seeing them connected in a point of view which will be new to several of them—the organic symmetry of beings; they will remark that what characterizes this manner of describing the organs—and which, I venture to believe, gives it more correctness and importance—is,

1st, That of considering each organ as being developed or proceeding from that which serves for its immediate support; or, in other terms, considering the exsertions and not the insertions.

2d, That of establishing as a rule (with exceptions for the convenience of speech), that every organ ought to retain the general name whenever its identity is proved; and that special names of organs ought only to be admitted when their identity of origin cannot be recognised, and not when they present an unusual form or appearance.

3d, That of reducing each part to its organic elements, which, once known, are considered as subservient to the general laws of union, abortion, and degeneration which I have established in the *Théorie Elémentaire.*

I have given to this work the name of Organography, and not the too restricted one of Anatomy, because the latter, which supposes a cutting of the integuments, is only a slight part of the study of the structure of plants, most of the organs of which are situated externally, and in which it also seems that the internal ones are often dependent upon the external. The anatomy, properly so called, hardly forms half of the first Book of the Organography; it is that part of the science in which the most doubts and ambiguities are met with, the application of which is the least frequent, and where the most celebrated observers are almost all at variance upon the most simple points of the observation of facts. Endeavouring to present this part of the science with as much correctness as possible, I have then, after the example of zootomists, given more importance to the study of complicated organs, the function of which is the most evident, the observation the most positive, and the knowledge the most important in the whole science.

In order to render the assertions of facts, of which this work is almost entirely composed, understood, I have been careful to quote numerous examples; and as one same example may frequently serve to elucidate the history of two classes of organs, I have not scrupled to mention it twice when I think it necessary. I beg my readers, beforehand, to excuse this kind of voluntary repetitions, which have most frequently been caused by the desire to quote for each case, examples the most convincing, or the most easily verified.

The alphabetical index to the names of the plants mentioned in the work, which will be found at the end of the second volume, will afford an easy means of referring to the observations which may be there contained; but I must beg those who thus go to search here and there for isolated facts, not to be surprised if they sometimes find them either devoid of proof, or difficult to understand; and I cannot tell how to conclude these lines without referring to the request which I have already made to my readers—not to judge of me by isolated facts, but upon my opinions taken collectively.

A. P. De C.

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VEGETABLE ORGANOGRAPHY.

INTRODUCTION.

To proceed with regularity in the description of the organs of plants, two absolutely different courses are presented to us. We can, in fact, after the example of Grew and Malpighi, examine successively each of the parts which offer themselves to us at first sight, and look for the elementary organs of which they are composed; or, following the route traced by Duhamel, Sénebier, and most modern botanists, we can first study the elementary organs which are common to all plants and all parts of plants, and afterwards consider how their combinations form the different parts of vegetables.

The first course, which is analytical, is necessarily that of the observer; it was that of the first phytotomists; it was, in fact, the only one which could be followed at the commencement of the science; and it is still that which one must embrace in the course of examination. But since long and laborious analyses have proved that the parts apparent in all plants are formed of a small number of organs resembling each other in different plants, it seems evident that conciseness and also clearness are gained by following the synthetical course; that is to say, by commencing first with the study of the elementary parts, in order to describe afterwards the compound organs which they form. This course, bolder and more concise, obliges us, it is true, to commence with the most obscure, uncertain, and difficult portion of Organography; it requires more trouble and attention on the part of observers; but it avoids frequent and fastidious repetitions, and furnishes some more precise data for the mass of the science: the little preliminary knowledge which it supposes, is limited to notions so simple, that every one possesses it without any study, and by the simple acquaintance with the most usual terms of language.

When we wish to describe first the compound organs, we are compelled, in order to impart the knowledge of their structure, to use terms, the meaning of which is little known without previous study—such as *cellular tissue*, *tracheæ*, &c. When, on the contrary, we commence with describing the elementary organs, we are constrained, in order to express their situation, to make mention of compound parts which have not as yet been explained; but these, such as the leaves, the bark, or the petals, are most commonly known, and consequently there is less inconvenience in speaking of them before having described them.

I will commence, then, by describing the elementary parts which compose the intimate tissue of all the organs of plants; after which I will describe the organic parts or the compound organs which serve either for nutrition or reproduction; I will reduce the exposition of the elementary parts to that which is common to the greater number of the organs of plants; and I will reserve for the history of the compound organs, the anatomical details which are peculiar to each of them.

Following this course throughout, I would here advise beginners, or those who do not wish to dive deeply into the study of plants, to commence the reading of this work with the Second Book, and to reserve the first for the end.

VEGETABLE ORGANOGRAPHY.

BOOK I.

OF THE ELEMENTARY ORGANS, AND OF THOSE PRIMARY COMBINATIONS OF THEM WHICH MAY BE CONSIDERED AS ELEMENTARY ORGANS.

CHAPTER I.

OF VEGETABLE STRUCTURE IN GENERAL.

THE intimate structure of vegetables, viewed under very powerful microscopes, offers little diversity. Plants the most dissimilar in their external appearance resemble each other internally in a truly extraordinary degree; all their organs present in the interior but one tissue, of a very homogenous nature, and which seems composed of parts, the structure of which in one plant scarcely differs from that in another, and the absolute dimensions of which are by no means in conformity with the whole size of the vegetable. Grew, who had first made this observation, has given to these parts the name of SIMILARY PARTS, because of this great resemblance which they present throughout the whole vegetable world. Sénebier has named them Elementary Parts; and I have adopted this last designation on two accounts; first, because it describes better the part which these organs perform in the vegetable economy; and, secondly, because the term used by Grew is not strictly in accordance with truth in the present state of the science; and without doubt it will always become less so, as we dive more deeply into the mysteries of Vegetable Organography.

Every one knows that organized beings are composed of solid and fluid parts; or, to speak in a more general manner, of tissues which form the body of beings, and of substances received into these tissues, or secreted by them. The first are those which constitute the peculiar nature, the life of the being: these are the elements, the modifications of which determine the afflux and the nature of the fluids; they are those alone which form the object of Anatomy, and with which we shall here occupy ourselves. As for the substances deposited, or the fluids, their particular study belongs to Physiology, and we shall only speak of them here incidentally.

The study of the elementary organs of plants was commenced about the end of the seventeenth century, a little while after the invention of the microscope.

Grew in England, and Malpighi in Italy, nearly about the same time commenced the examination of Vegetable Tissue, availing themselves of the assistance of this invaluable instrument; and observed all its parts with more or less precision: thenceforth this study was continued by Leeuwenhoeck; afterwards, about the middle of the eighteenth century, Gleichen, Needham, and some others, began anew to apply themselves to it: Hedwig, again, enlarged its boundaries, either by his genuine discoveries, or by his ingenious hypotheses.

In our own time, Mirbel, Link, Treviranus, Sprengel, Rudolphi, Kieser,* Dutrochet, and Amici, have published very minute examinations of the Vegetable Tissue, and accompanied them with drawings, both numerous and accurate; but the necessity of continually employing in these researches an instrument so difficult to manage well as the compound microscope, rendered abortive the dexterity of these observers: the minute anatomy of vegetable structure is still, in the more fundamental points, in a state of uncertainty discouraging to the friends of the truth. "If any thing," says Dutrochet, (Mem. Mus. 7, p. 385,) "can prove the uncertainty of our information upon vegetable organization, it is the difference of opinion existing amongst naturalists upon this subject." There is, in fact, hardly any point in vegetable anatomy, upon which we do not find that those who have devoted themselves to it with the most care, are divided, not only upon the theory, but even upon the facts, which one would think observation should immediately decide. The contradictions of observers of these points are so great, that it is not an unfrequent occurrence for several persons viewing together the same fragment, with the same microscope, to see, or to think they see, different appearances. For a much stronger reason, are separate observers unable to understand each other upon the most simple

* Those who wish to study the elementary organs of plants more in detail than the limits of this work have permitted me to assign to them, will find an excellent review of this branch of the science in the Mémoire sur l'Organization des Plants, published by M. Kieser, (Haarlem, 1812, 1 vol. 4to.) This work contains a great number of well-observed facts; and it is important to readers of French, inasmuch as it is the only work written in this language which gives an idea of the labours of the Germans in phytotomy. I regret much, myself, that my ignorance of the German language has prevented me from studying these works in the original to the extent which I should wish. I beg these learned men may be indulgent, if I have, contrary to my intention, either omitted to quote their observations, or represented their opinions inaccurately.—A. P. De C.

facts. For fear of seeing these discrepancies multiplied, we conclude by distrusting our own eyes, and by fearing to affirm any thing concerning what we believe we have seen. I shall endeavour to develope on this occasion, with all the caution which the obscurity of this part of the science demands, what appears to me most worthy of attention. I shall report with care the opinions of various observers, in order to endeavour to understand well those points upon which a difference exists, and those upon which they are agreed. But before entering into this exposition of the doubts and the uncertainties of microscopic anatomy, I would first inform beginners, that these doubts have much less influence than might be believed upon the whole of the science. I will also say, in concluding these preliminary observations, that the precautions which have always proved the most sure for avoiding microscopic illusions, are—

First, Never to observe an object of considerable size, without having commenced the observation with glasses of weaker power,—so as to follow it in a gradual manner from the lowest to the highest degree of enlargement.

Secondly, To view the same object with microscopes of different constructions, so that one may destroy any illusion which another may have produced; by these precautions the number of facts which are affirmed is perhaps slightly diminished, but more certainty is given to them.

When a transverse section of a plant, or a part of one, reduced to a thin and transparent slice, is examined first with a lens, and afterwards with a microscope, we perceive unequal cavities, sometimes round or angular, and most frequently hexagonal. If a longitudinal section be made, we always find the cavities closed by diaphragms; frequently there are other tubular cavities without transverse divisions, and sometimes widely scattered filaments more or less opaque. The entirely closed cavities have been called CELLULES or UTRICLES; the tubes, VESSELS; and the filaments, FIBRES.

If we now survey the various opinions which have been formed upon the structure or general organization of vegetables, we see that all the systems of phytotomists may be reduced to three principal ones. Some, after the example of Theophrastus, and perhaps of Grew, have thought that all the vegetable tissue is formed of very minute fibres differently interwoven. Others—and Mirbel appears to be the first who ventured the opinion in a general manner—believe that it is a perfectly continuous membrane, the various doublings of which produce the closed or tubular spaces which we observe. Lastly, most modern observers, following that which appears to have been the opinion of Malpighi, admit that vegetables are essentially composed of Cellules or Utricles differently joined together, and of Vessels, which, by different modes of development and cohesion, form all the organs.

The comparison of these three theories will naturally lead to the exposition of the facts upon which we are about to enter; passing in review—

1st, The CELLULAR TISSUE.

2d, The VESSELS.

3d, That which is called the FIBRE of plants.

4th, The EPIDERMIS, or CUTICLE, which covers all this apparatus.

CHAPTER II.

OF CELLULAR TISSUE.

SECTION I.—*Of Cellular Tissue in general.*

THE CELLULAR TISSUE *(contextus cellulosus)*, considered collectively, is a membranous tissue, composed of a great number of cellules or cavities, closed on all sides. The froth of beer, or a piece of honeycomb, gives a rude but pretty accurate idea of it; each wall of water or wax represents the membrane, and the place of the air or the honey gives the idea of the cavity or cellules. This tissue has also received the name of the UTRICULAR TISSUE *(complexus utricularis)*, which makes a more particular allusion to the theory, in which we admit that each cellule is a perfectly distinct vesicle. Link has named it *Tela Cellulosa*, and others *Complexus Cellulosus.* When considered collectively, and in contradistinction to parts which are furnished with many vessels, the name of PARENCHYMA has been given to it.

The cavities of cellular tissue bear the name of CELLULES *(cellulæ)*. Malpighi, who considered them as so many distinct vesicles, calls them UTRICLES *(utriculi)*. Grew has indifferently described them under the names of CELLULES, PORES, and VESICLES.

The cellular tissue is found in all plants: there are even some which are entirely formed of it; such as the Algæ, Fungi, Hypoxylons; Lichens, and most probably Hepaticæ and Mosses, or in other words, all the true Acotyledones. As for other plants, although not entirely composed of cellular tissue, it is found in them very abundantly; it everywhere encircles the vessels; so that in the vegetable, as well as in the animal kingdom, the vessels are never found destitute of covering: fruits, fleshy leaves, pith, the bark of roots, &c. present a great mass of cellular tissue. Regard being had to proportion, it is more abundant in herbaceous plants than in trees; in young plants than in those which are aged; in fleshy parts than in these which are dry and fibrous; and it seems entirely to compose plants at the period of their first development. The walls which form the cells are of transparent membrane: these easily swell up by maceration in water, and rapidly shrivel and become obliterated by exposure to the air; so that their examination requires some care. These membranes are generally without colour when they are properly deprived of the sap stored up in the cellules.

The diameter of the cellules varies much; in general, the larger it is, the more the part to which it belongs has a loose texture, or the more rapidly it grows. Kieser calculates, that the largest cellules—those of the Gourd, for instance, or of the Balsam, under a magnifying power of 130 times their diameter, are from five to six millimetres;* and that the diameter of the smallest, as, for example, those of the leaves of the Wallflower,

* A millimetre is about equal to $\frac{1}{26}$th of an inch. It is the thousandth part of a metre, a French measure, which is equal to about thirty-nine inches English.—B. K.

is not, under the same magnifying power, more than one millimetre; so that there are 5,100 cellules under a millimetre square of the natural size.

Section II.

Of the different Forms of the Cellules.

The Cellules of cellular tissue, considered only as to their general form, present themselves under four principal forms: viz. 1st, round; 2d, spindle-shaped, or tapering towards the two extremities; 3d, tubular, or prism-shaped, that is to say, not narrowed at the extremities; 4th, elongated transversely.

The ROUND (Pl. 1, fig. 1) seems to be the original form of the cellules; and it may be said in this sense, that all the other appearances which they present, result from the unequal pressure which they exercise on one another during their growth; that they thus become hexahedral, or nearly so (Pl. 1, fig. 2, 4, 5, and 6), when they are equally pressed on all sides; that they take an elongated form, either in a horizontal direction or in a transverse one, when the pressure is exercised on one or the other side: but in all these cases it is necessary to be careful to remember, that the forms of the cellules will not be as regular as the figures which have been published would lead us to think. It is evident that, in representing them with the exaggerated regularity which the majority of plates exhibit, one would wish either to point out that state which one would suppose normal, rather than to represent exactly the appearance of these organs from simple observation; or to disentangle the examples of numberless anomalies, which the impulse of vegetation occasions in the form of cellules. Pollini has particularly insisted on the variety of the form of the cellules in one and the same organ.

The cellules which are termed *round* or *hexahedral*, compose the cellular tissue called regular, that is to say, which is not perceptibly lengthened in one direction more than another. These cellules compose the pith of trees, the cellular envelope of the bark, the flesh of pulpy fruits, the parenchyma of leaves, and, in general, all the parts of plants which are susceptible of little or no elongation.

The Tissues which Link describes under the names of *Globular*, *Vesicular*, or *Irregular*, appear to me to be modifications of that which we here name *Round Cellular Tissue.*

This round cellular tissue is destined, according to Link, to preserve and to elaborate the sap. Dutrochet assures us, on the contrary, that sap is not usually found here. The difference between these two assertions, resides probably in the meaning which is attached to the terms: if it is understood by the *sap*, the juice not yet elaborated, and which is proceeding to the foliaceous organs, there to receive the action of the air and light, it is consistent with truth to say that the round cellules do not contain any of it: if the word *sap* is used to express a juice which has already undergone some elaboration, or which is placed in a situation to receive it, in that case we can say that the cellules contain this juice; and what happens in the parenchyma of fruit during their maturation, seems to me to prove it.

Cellules elongated in a longitudinal direction, (Pl. 1, fig. 7) are sufficiently different from the preceding, and even sometimes come nearer in *their* form to true vessels. Mirbel described them first under the name of LITTLE

TUBES (*petits tubes*), and has considered them as modifications of vessels; but it is evident to any one who may have observed them, that they are not vessels, because they are closed at the two extremities;—this is the reason why, in the elementary principles placed at the head of the third edition of the *Flore Française*, I have described them under the name of TUBULAR CELLULES (*cellules tubulées*), which indicates their form well enough; and I have given the name of ELONGATED CELLULAR TISSUE to that which is formed of them. Rudolphi actually viewed them in the same light, and described them under the name of ELONGATED CELLULES (*cellules alongées*). Mirbel has finished by adopting the same opinion, and has described this organ, when in a mass, at first under the name of WOODY CELLULAR TISSUE (*tissu cellulaire ligneux*), because he found it in abundance in wood; and afterwards under this of ELONGATED CELLULAR TISSUE (*tissu cellulaire alongée*). Treviranus has likewise coincided in this opinion, and has given to these cellules the name of FIBROUS UTRICULES (*utricules fibreuses*). Cassini has called them LITTLE TUBES (*tubilles*).

After the observations of Kieser and Dutrochet, it appears to me, that two very different states of cellules elongated in a longitudinal direction must be distinguished, viz:—

1st. *The Cellules which enter into the composition of wood and of the cortical layers.* They have the appearance of spindles, tapering to the two extremities (Pl. 1, fig. 7); and Dutrochet has given them, from this circumstance, the name of *Clostres*, which signifies a spindle.

These *Clostres* are commonly parallel to one another, touching by their swollen parts; and the intervals which they leave at their extremities are filled up by the points of the neighbouring *Clostres.* They are filled with a particular matter, more watery in young wood than in old; and the nature of which determines the hardness, the weight, the varying colour of different woods compared together, and of the same wood at different periods and from different parts of the same plant. The tissue, described by Link, under the name of the Tissue of the Alburnum *(tissu d'aubier)*, comes under this class.

2d. There are other cellules to which the name of LITTLE TUBES *(tubilles)*, (Pl. 1, fig. 8; Pl. 2, fig. 1, 3) proposed by Cassini, will be tolerably well adapted: these are *cylindrical*, or *prismatic*, and are not swelled out in the middle of their length. They are always found around the vessels of vascular plants; and they alone compose the nerves, peduncles, and stems of plants destitute of vessels, as the Mosses and Algæ. It must be remarked, that in several of these cellular plants, as the Mosses and Hepaticæ, there is suddenly a remarkable change of figure among the elongated cellules which form their nerves, and the round cellules which compose their parenchyma; whilst in vascular plants there often is an insensible transition of form, of elongated cellules which surround the vessels, to the round cellules which form the parenchyma. Rudolphi concludes from this, that the elongated cellules of Mosses might well be considered as a particular class of vessels; but this opinion does not appear to us to be sufficiently proved by this sole consideration.

Lastly. There is a final order of cellules, which, instead of being lengthened in a longitudinal direction, are elongated *transversely* (Pl. 1, fig. 9, 10): these are the cellules which compose the medullary rays, and which are necessarily peculiar to the class of Dicotyledons. Kieser, who first proposed to distinguish them as a particular class of cellules, observes that they are remarkably smaller than all the others.

All these cellules, elongated either in length or breadth, seem less adapted than the round for the elaboration of the sap, but appear to assist perhaps in its progress; this is, at least, what may be concluded from their habitual presence in the organs where the fluids are in motion, and, at least as regards the Little Tubes *(tubilles)*, from the fact that they compose the largest part of the organs where the motion of the juices appears to be performed.

Section III.

Of the Substances contained within the Cellules, and of the Appearance of their Walls.

The Cellules, examined in different plants, or at different periods of their growth, are sometimes full of a watery juice, and sometimes of air: in neither of these cases is their transparency affected; and the history of these substances contained in the cellules, most important in Physiology, has not been confounded by anatomical errors. But it is necessary to remark, that besides these fluids, we meet with in these cellules different opaque or coloured bodies, which deserve some attention.

1st. There are frequently found little moveable granules, opaque and colourless, which are of an amylaceous nature, and bear the name of Fecula; these granules are formed in considerable quantity in certain parts of the tissue—as, for example, in the fleshy Cotyledons, and farinaceous albumen of seeds, the parenchyma of tubercles, &c.

2d. There are also found in the cellules of the foliaceous parenchyma other little globules, more frequently applied to the walls, which are generally coloured green by the action of the light: they are capable of assuming different colours; but remain colourless, and scarcely, if at all, visible in the parts not exposed to the light. These globules are of a resinous nature, and constitute the green matter of leaves, or that which some chemists call *Chlorophylle.* The coloured globules of the cellules of flowers may be compared with this class of bodies, for several reasons. It results from several very curious experiments, performed by Macaire, that this same matter is coloured red or yellow in the autumn, and that this is the same matter which, differently coloured, is again found in the calyx, and even in the corolla and the other parts of fructification; consequently the name of *Chlorophylle* is very improper: we may, by analogy with the word *fecula,* term it CHROMULE.

3d. Finally, the cellules of wood, of alburnum, and of the layers of the bark, contain, according to the observations of Dutrochet, granules of woody matter, which are applied to their walls, encrusting them, and rendering them opaque, constituting the differences so remarkable among the different woods.

If we remove these three classes of matter, the tissue of the cellules, viewed under very powerful microscopes, appears perfectly transparent, and represents neither regular folds, nor dots adhering to it, nor visible pores. Mirbel has vigorously supported the contrary opinion, and has even represented the round cellules marked with pores, encircled by a raised border, or with transverse slits; but no other phytotomist has ever seen the like. It appears that this error arose in different cases, from one of the two following causes:—

1st. One might take the amylaceous granules whilst they adhere a little to the walls, or those of the colouring matter and of the woody matter, for integrant parts of the tissue.

2d. In the opinion of those who consider the Strangulated Vessels *(vaisseaux en chapelet)* as kinds of cellules, we might be justified in saying that their tissue was dotted; but still, even in this case, it was very hazardous to call them porous. We will examine the nature of these markings of the tissue, when we direct our attention to the different classes of vessels. We digress for a moment, to prove, after the almost unanimous testimony of anatomists, and even our own observations, that cellules properly so called, whether round or elongated, are formed of a transparent tissue, which is neither dotted, nor pierced with visible pores, nor still less marked with transverse slits.

Section IV.

Of the Relation of the Cellules mutually, or of the Continuity of the Tissue, and of the Intercellular Passages.

The most important question which can present itself upon the nature of the cellular tissue, is to know if all the parts which compose it are distinct bodies, more or less united to each other, or if they are the doublings of a single continuous membrane. This question affects almost all those which we shall have to examine hereafter upon the organic nature of vegetables; and it is the basis of all discussion upon the use of these same organs. We shall endeavour to explain it with as much clearness as the difficulty of the subject will permit. It is not easy to affirm, in a very positive manner, what was the opinion of Malpighi; and probably he had not formed any decided one upon the subject: nevertheless, the name of *Utricle* or *Vesicle*, which he has given to the closed cavities, and most of the figures which he has published, afford us grounds for presuming that he regarded each of them as a separate little body, furnished with its own partitions, and simply adhering to or in juxtaposition with the neighbouring bodies; whilst, on the contrary, Grew, in giving to these same cavities the names of *Pores* or *Cellules*, has more clearly indicated that he considered them as cavities combined together into a tissue or a texture, continuous in all directions, of such a kind that each of them is separated from its neighbour by a single and simple partition. In accordance with the opinion which Malpighi appears to have entertained, Leeuwenhoeck seems to admit the existence of distinct utricles bound together by intermediate fibres. Hedwig and Mayer have considered the cavities as the receptacles destined to receive the liquids, and have admitted that many little vessels wind spirally upon their walls.

Treviranus and Kieser have maintained that vegetables are composed of vesicles more or less joined together, separated by visible interstices, which they have described under the name of INTERCELLULAR or INTERVASCULAR PASSAGES *(méats intercellulaires ou intervasculaires)*, Pl. 1, fig. 1, 3. Link has adopted the same opinion, and says, that he has frequently seen the cellules isolated, especially when he has subjected the tissue to boiling in water. Du Petit-Thouars admits likewise, that these cellules or utricles are bodies distinct from one another. Pollini favours the same opinion, from peculiar observations of his own. Amici avers, that not only, by means of his microscope, he can see the intervals of the cellules, which often appear as angular spaces full of air, but that he can, having boiled the tissue, detach the cellules from one another, and observe them isolated; so that, according to him, one cannot deny the existence of these spaces or intercellular passages, which are filled with air. Dutrochet says, that the cellules, having been boiled in nitric acid, separate, and appear as so many distinct vesicles; but moreover, where two cellules touch, the wall which separates them presents a double membrane; that there is never a wall common either to the cellules or to the vessels; and that the hollow organs have no other mutual relation than that of contiguity. Finally, Turpin admits likewise, that vegetables are entirely composed of distinct vesicles, variously combined, or sometimes perfectly free; and he proposes to give the name of *globulin* to this vegetable element.

The contrary opinion, maintained, it is said, first by Wolf, has been vigorously adopted by Mirbel, who admits as the fundamental base of anatomy, that vegetables are entirely composed of a tissue continuous throughout all its parts; that the neighbouring cellules have always a common wall; that there are also tubes resembling the neighbouring cavities; that when one thinks he has seen a double partition, it is because he has seen by its transparency the sides of some other cellule. This opinion has been adopted by Rudolphi, and I myself formerly supported the elementary theory. The partisans of the two opinions rest for support upon the same comparison. Grew had said that the cellular tissue resembles the froth of a liquor in fermentation; Mirbel approves of this comparison thus far, that in froth each bubble of air is separated from its neighbour by a single film of water, and that the films are continuous one with another. Link approves of it also, for this reason, that each bubble of air must be considered as surrounded by a watery membrane which is peculiar to itself; and that, when they unite to form the froth, each film of water is formed of two films adhering together. Thus the partisans of the two theories are divided even as to the meaning of simple metaphors.

Shall we venture to affirm any thing decisive between these diametrically opposite opinions? Is there any intermediate theory which may reconcile them? 1st. Microscopic observation directed to this point has frequently left me in doubt: the membrane which separates the cellules appears simple with a microscope of small power; but as soon as we employ a powerful instrument we very often can no more venture to affirm whether we see a single or a double membrane; and when it appears double, whether this effect is due to some projecting shadow. One thing I can affirm, and that is, that I have seen triangular spaces between the cellules, as are represented in the figures of Treviranus, Kieser, and Amici; and that with them I am inclined to consider them as spaces filled with air: but one cannot conclude from this that the tissue is not continuous for it might easily happen that there might be among the cellules full of juice some empty cellules, which would present this appearance. Grew himself, always admitting the simple nature of the membrane, has very frequently represented intervals between the cellules, very much the same as the authors whom I have previously quoted. 2d. In tearing irregularly the tissue of a leaf, I have frequently seen, especially in the leaves of Monocotyledons, some cellules which appear perfectly untouched, separated entirely or in part from their neighbours; but these facts are so rare, that one cannot but think that they are either out of the ordinary course of things, or that the tissue of neighbouring cellules has perhaps been broken.

3d. The separation of cellules by boiling in water or in nitric acid, seems likewise to confirm the idea of the double nature of the membranes, and tends to make us consider the cellules as distinct bodies. But it must also be confessed that, in subjects so difficult, it is dangerous to decide after observations where the natural tissue has been altered by such powerful agents. The boiling in water itself has all the inconveniences of the maceration formerly made use of—that is to say, it destroys the delicate intermediate organs, and tends to isolate artificially organs which may in reality be continuous in their natural state.

4th. There are some cases where one sees the cellular tissue resolve itself into isolated bodies, which at first sight appear like dust, and which, viewed through the microscope, evidently appear as cellules: of this kind are the mass of globules which are found in Lenticels upon the development of adventitious roots, &c. From the general result of these observations, I do not now retain any doubt that the cellules which compose the cellular tissue in general are vesicles distinct from one another and differently joined together.

If I wished to search in nature for an example of this kind of structure, which, though rude, should be visible to the naked eye, I would cite the membranous vesicles, full of juice, which are found in the interior parenchyma of the orange: each of these little sacs, which I do not pretend to compare completely to the cellules, is found nearly free, and they collectively form a species of parenchyma.

Where the cellules are lightly or partially united, they may be found disunited entirely or in part; as is seen, for example, in the loose tissue of the leaves of several Monocotyledons.

If any cause, altering the ordinary state of vegetables, should chance to break the adherence of the cellules, some may then be found disunited, and having the appearances of little vesicles; as, for example, at the instant of the development of the adventitious roots, and perhaps in the efflorescence of lichens.

In numberless cases where the cellules are intimately united, there are often found between them empty spaces, which are the intercellular passages; to which we shall return presently.

Finally, there are cases where the union is so intimate that it cannot be perceived: this is what happens particularly in the cellules of cryptogamic plants, among which the intercellular passages are not visible, and the partitions which separate the cavities appear to be simple.

The Intercellular Passages or Canals, then, are the spaces which exist between the cellules, and which have no other walls than those of the cellules. Their form is most frequently that of a triangular prism: they are found, according to Kieser, hexagonal or even dodecahedral, according to the number of the walls of the cellules which concur in their formation. These canals follow the general direction of the cellules, either lengthways, which is the case most frequently, or transversely, as in the medullary rays. They are often full of water, sometimes of air, and appear also to receive the proper juices. Their size varies much in different plants; they are generally larger in those with a loose and succulent tissue; but their situation and history are still very obscure, and deserve to occupy most particularly the attention of anatomists. We will return to this subject in speaking of the Air cavities, and Receptacles of proper juices.

It must be seen from the foregoing, that the principal property of the cellules or vesicles forming the cellular tissue, is the faculty of uniting together. This property plays an important part in the whole history of vegetation: not only to its different degrees are all the internal appearances of the tissue to be referred, but also it is these combinations of the cellular tissue that cause all the combinations of the different organs, which, at first being distinct, finally form a single texture, in appearance simple, in reality compound.

A second peculiarity of the tissue of the cellules is, that they are eminently hygroscopic; that is to say, that they absorb water with which they may be in contact, and in particular that which is conveyed by the Intercellular passages. Probably this water, deposited in the cellules, undergoes a particular elaboration, from which results the formation of the substances which are observed in them. This hygroscopic property has appeared to me for a long time, as it did to Sénebier, to be one of the principal bases of the phenomena of vegetable life. Kieser has also insisted, on a later occasion, upon its importance.

Finally, the third property of this tissue appears to be organic contractility; a phenomenon purely physiological, which I ought only to mention incidentally in this place, but without which it is difficult and perhaps impossible to comprehend the course of the sap.

Section V.

Of the Origin of the Cellules.

The origin of the cellules, like all which relates to the origin of organized beings, is a problem absolutely impossible to be solved in the present state of our knowledge. Two opinions on this subject have been put forth by naturalists. Treviranus appears disposed to think that the amylaceous granules which are found in the cellules are the rudiments of new cellules, which, being developed, tend to increase the mass of the tissue. It seems that Raspail has adopted this opinion, from the manner in which he considers the fecula of the Gramineæ.

Kieser thinks, on the contrary, that the globules which are found swimming in the juices of the inter-cellular canals are the rudiments of young cellules, which, deposited here and there in their route, tend to increase the mass of the tissue.

Without affirming any thing on a subject so obscure, I am, for the present, more disposed to admit this last opinion; because the first supposes, either that the amylaceous granules come out of the cellules, which seems inconsistent with the absence of any visible pore; or that they break, in their development, the cellules whence they have taken their origin, which point has never been seen to take place. Finally: I only advert to these opinions as curious points of meditation; and I am cautious in taking up any decided opinion upon subjects so difficult.

Section VI.

On the Physiological Function of the Cellules and Intercellular Passages.

The physiological function of the cellules is a subject entirely belonging to Physiology, and one which we can only here examine in a very brief way, and solely in an incidental manner.

The cellules, being closed on all sides, can only receive the sap by means of the hygroscopicity of their walls. Those which are round suck up the juices which surround them, and elaborate them in their interior: and it is thus that, by a vital process, they form the feculent and mucilaginous substances, and the resinous matter which gives them their colour. We also see these different substances abound in all parts of plants which are essentially composed of round cellules; as the parenchyma of the external covering of leaves and fruits, the pith and the receptacles of flowers, &c.

As to the elongated cellules which surround the vessels, the part they perform is very difficult to comprehend: one never finds there the substances which we have noticed; and, for the most part, they appear empty, or else filled with air, and in consequence participate in the function of the vessels.

The intercellular passages are generally full of sap, and it is very probable that they are the parts which serve essentially to its progress. We can, in this point of view, divide them into three classes:—

1st. The intercellular passages, situated between the elongated cellules which surround the vessels, appear to serve for the ascent of the unelaborated sap, which, from the roots, spreads throughout all the foliaceous parts of the plant.

2d. The intercellular passages situated between the cellules of the medullary rays establish the transverse communication of the sap, from the centre to the circumference.

3d. The passages situated between the round cellules of the parenchymatous parts receive the sap in larger quantity, considering that their movement is slower. The cellules are thus surrounded by sap, which they can imbibe for the purpose of elaborating.

We shall see hereafter, that intercellular passages, when dilated, produce the greater part of the Air cavities, and Receptacles of proper juices; and present thus new support for the life of the vegetable.

We must not lose sight of the fact, that the cellular tissue is the only elementary organ which exists in the whole vegetable kingdom; and consequently it is to it, and its modifications, that we must refer all the more general phenomena, the ascent of the sap, and their principal elaboration.

CHAPTER III.

OF THE VESSELS.

Section I.—*Of the Vessels in general.*

Of all the parts of vegetable anatomy, the structure and history of the Vessels is that about which there has been most dispute, and upon which there is still but little accordance.

We describe under this name (adopted from analogy with animal anatomy) those cylindrical, or nearly cylindrical tubes, which are observed in the greater number of vegetables; and which differ from even the most elongated cellules, both because there is not found in them any diaphragm which closes them in a transverse direction, and because their walls are marked with dots, stripes, rings, slits, or spires, which are not to be found on the walls of cellules.

For a long time, vessels have been distinguished into Proper Vessels, and Lymphatic Vessels. Under the former name were described the tubular cavities which contained the peculiar juices of certain plants; such as the milky, resinous, &c. Under the second were comprehended all the tubes full of air, or of water, which is but little if at all elaborated. But it has been since found, that the Proper Vessels are not true vessels, but peculiar modifications of the cellular tissue, which we shall afterwards describe under the name of Receptacles of proper juices. We shall only comprehend, then, under the collective name of Vessels, those which have been long described under the name of Lymphatic Vessels; but as this appellation, founded on the function which is attributed to them, is itself only hypothetical, we shall not adopt it, since it becomes useless the moment that the Receptacles of proper juices are no longer confounded with the vessels.

These vessels, termed Lymphatics, have been described in English, by Grew, under the names of Sap Vessels or Lymph-ducts: others have named them Sap Vessels *(vaisseaux séveux)*; and Mirbel describes them under the name of Great Tubes *(grands tubes)*. Kieser comprehends them collectively under the name of Spiral Vessels *(vaisseaux spiraux)*, which is only applicable to one of the forms under which they are presented to us. These vessels present five very distinct varieties of form, viz.—

1st. TRACHEÆ *(trachées)*.

2d. ANNULAR or STRIPED VESSELS *(vaisseaux annulaires ou rayés)*.

3d. DOTTED VESSELS *(vaisseaux ponctués)*.

4th. STRANGULATED, MONILIFORM, or NECKLACE-LIKE VESSELS *(vaisseaux en chapelet)*.

5th. RETICULATED VESSELS *(vaisseaux réticulaires)*.

We shall commence by describing them separately; then we shall occupy ourselves with discussions which divide anatomists upon their reciprocal relation, their history, and their use.

Section II.

Of Tracheæ, or Spiral and Elastic Vessels.

The Spiral Vessels (*vasa spiralia*), or the Tracheæ (*tracheæ*), or, as Cassini calls them, the Helicules, (Pl. 2, Fig. 1, *a a*, 3, 4,) are organs of an entirely peculiar kind, and about the structure of which there has been much dispute. Henshaw discovered them in the Hazel in 1661, that is to say, a year after the completion of the microscope by Hook. Malpighi, who first examined them with care, compared them to the tracheæ of insects, which name he has retained: he regarded them as the respiratory organs of plants, and described them as tubes formed of a band rolled spirally upon itself, capable of unrolling with elasticity. The unrolled tracheæ can be easily seen in breaking a young shoot of the Rose or Scabious. A trachea, seen by the naked eye or through a lens, presents the appearance of a brilliant silver band rolled spirally, as a spring in a funnel. Duhamel compares it to a riband which has been rolled round a cylinder, and which by its spiral circumvolutions would form a continuous tube; Mirbel confirms this opinion of the structure of the trachea, and only adds that the edge of the band is a little thicker than the middle. Hedwig, on the contrary, has described these same organs in a manner entirely different; he names them *Vasa pneumatochymifera*, and believes them to be formed of two distinct organs: he thinks that that which was considered to be a band previous to his observations, is a real tube, which is rolled spirally upon another straight and central tube:

he imagines that these spiral tubes are destined for carrying the sap, and he calls them for this reason *Vasa adducentia spiralia, Vasa chymifera hydrogera;* on the contrary the central tubes may always be full of air, whence he has given them the name of *Vasa pneumatophora.* Schrader and Link differ from the opinion of Hedwig in this,—that instead of admitting that the spiral is formed by a tube, they think that it is composed of a band hollowed out into a gutter in its internal part. Bernhardi, on the contrary, admits that there is an upright membranous tube, continuous and transparent, in the interior of which is rolled a spiral band which serves to keep it open; and which, proceeding to unroll itself with elasticity when the exterior tube is broken, only appears to our eyes under the name of trachea. He supposes that this same band exists in the tubes of all vessels; that when it is continuous and spiral, it forms the trachea; when it is divided into interrupted lines, the striped vessel, (Pl. 2, Fig. 2, *a*;) and more interrupted still, the dotted vessel, (Pl. 2, Fig. 2, *b*.) Kieser calls what we name trachea, a simple spiral vessel; and he believes that membrane exists neither on the inside, nor on the outside, nor among the spires. Lastly, Dutrochet admits that the spires of the tracheæ are united by an intermediate transparent membrane, which is torn when the spiral thread is unrolled; he believes that in their natural state they have not any openings, but that they form a continuous tube.

To attempt to choose our opinion in the midst of so many contradictions, it is necessary to discuss separately each of the assertions of these authors, and to divest them as much as possible of all systematic idea.

1st. *Does there exist in the interior of the spire a peculiar tube, as Hedwig was the first to assert?*—Let us remember that this tube has only been seen by a small number of observers, and that Hedwig himself seems less to have seen it, than to have conceived it in theory; for notwithstanding his skill as a draughtsman, he has not ventured to give a drawing of it. Link says that the observation of Hedwig has not been confirmed by any anatomist; and, for my part, I do not deny this assertion. Mirbel assures us that, in some cases, the old tracheæ present in the interior a kind of incrustation more or less dense, which resembles a true internal tube; but as this appearance of the interior tube is very rare, one would be authorized in not considering it as an integral part of true tracheæ.

2d. *Is the part which forms the spire* flat, *as former observers asserted; or is it a* little hollowed into a channel *and* bordered by a thickened rim, *as the figures of Mirbel indicate; or is it* tubular, *as Hedwig and Mustel affirm?*

The greater number of observers are opposed to this last opinion, although several among them have observed the tracheæ with more powerful glasses than those of Hedwig. Still later, Amici, who makes use of the strongest microscopes known, remains in doubt concerning the tubularity of the tracheæ; and believes that the question cannot be solved by the optical means which we possess. One of the arguments which appears to have persuaded Hedwig to admit the tubular nature of the spiral part, is, that when a coloured liquid rises in these organs, one distinctly sees that it follows the spire; but this appearance is as easily explained by admitting that it is a band a little concave, along which the coloured liquid glides, as in supposing it to be a perfect tube. Nevertheless, the hollow form of the band, or the existence of the rims, is still contested by several of the most able observers. Kieser, in particular, without affirming that the spire is tubular, believes that it approaches the cylindrical form; and as for myself, it appears to me flat, with the two borders more or less opaque and probably a little prominent (Pl. 2, fig. 4).

3d. *Is the spire of the trachea contained in a particular tube, as Bernhardi would have us think?* — I believe that we cannot deny the existence of this tube, but it is necessary to know whether it is one which might be formed by the edges of neighbouring organs, or whether it is a part of the trachea. Dutrochet admits the existence of a tubular membrane, which is not on the outside of the spires, but between them. The existence of a membrane which would unite the spires together, appears confirmed by the existence of tracheæ which are incapable of being unrolled, mentioned by some authors; but they have never been seen in a clear manner, and probably they are nothing more than annular vessels, of which we shall speak hereafter.

According to Mirbel, the tracheæ are continuous with the cellular tissue by their extremities; according to Dutrochet, they terminate, by their two extremities, in a very acute conical spire.

The spires of the tracheæ, according to Hales, are always rolled from right to left; this disposition appears, in fact, the most common, but Link has remarked some which were rolled from left to right.

Mirbel, Rudolphi, and Kieser, have discovered some tracheæ with a double and triple parallel spire; I have counted some even with seven in the tracheæ of the Plantain *(Musa paradisiaca,)* Pl. 2. fig. 3; and M. De la Chesnaye says that he has counted up to twenty-two. Rudolphi says that the tracheæ also have a doubled, or a multiplied spire, in *Canna*, *Amomum*, *Kæmpferia*, *Maranta*—genera all allied to *Musa;* and even, he says, in *Heracleum speciosum*, which belongs to a very distant family. Kieser has remarked, that in the greater part of vegetables the tracheæ which are furnished with a simple spire are disposed in bundles: on the contrary, we find them solitary in the Banana, which has the spires multiplied; whence one might infer, that this multiplied spire is formed by the union into one single tube, of filaments usually distinct.

Malpighi and Reichel say that they have observed contractions in the tracheæ, but no subsequent observers have seen them. Mirbel asserts positively that these are optical illusions. The diameter of the tracheæ is about the twenty-fourth of a line, according to Mirbel; but according to Kieser, their diameter is very variable in different plants.

Malpighi says that, "during the winter, the tracheæ are endowed with a vermicular movement, which delights the observer." It appears that this anatomist has here attributed to irritability, that which arises simply from hygroscopicity combined with elasticity. A motion in the tracheæ, when laid open, may be occasioned either by approaching and removing the ends of a young shoot broken across, or by exposing them alternately to moisture and aridity. Mirbel asserts that the tracheæ of the *Butomus umbellatus*, once unrolled, never contract again. The tracheæ are very visible in most of the young shoots of the year, especially in those which can be broken clean off without tearing them, as those of Roses: they are to be found, according to the observations of Mirbel, only around the pith in the old stems of Dicotyledons; for it appears that all that former observers have said of tracheæ observable in the wood, must be attributed to the striped vessels: the tracheæ appear to be organs essential to the medullary sheath, and they are to be found there, in the form of those which are incapable of being unrolled, even in aged trunks of trees, and in wood which has long been cut down. In the fibrous bundles of the herbaceous stems of Dicotyledons, the tracheæ are found, according to Kieser, in the part nearest the centre of the stem; among Monocotyledons, they are found in the woody bundles: according to Mirbel, they occupy the centre of them; Amici appropriates this place to the dotted vessels. The stem of the Plantain appears to be almost entirely composed of tracheæ, when it is cut across; they are so abundant, that in the Antilles they gather them by handsful, and a kind of tinder is made of them, which has long been publicly sold there. M. De la Chesnaye says that each Plantain tree yields five or six *grammes* (a drachm and a half) of these vessels, and that they may be used either in making a species of fine down, or may even be spun. Tracheæ are also found in the veins of leaves, in the corolla and sexual organs, but never in the bark. Mirbel says that they are very rare in the roots. Dutrochet asserts, and my own observations agree with his, that the tracheæ are absolutely wanting in the roots; and that those who have fancied they have seen them, must have taken for true roots subterraneous stems which have tracheæ just as aërial stems. Perotti must, therefore, be quite wrong when he says that the roots differ from the trunks in having the tracheæ more visible and more numerous. Tracheæ are entirely wanting in all cellular plants, such as the Mosses, Hepaticæ, Lichens, Fungi, Algæ, and *Chara*.

Some naturalists, upon whom we may rely, assure us that tracheæ exist in some Mosses, as in *Splachnum;* but this is doubted by several—as, for instance, by Rudolphi and others. Without denying that a negative observation has not so much weight as a positive assertion, I am of this last opinion, as I have never been able to discover them. Others consider the elaters of the Hepaticæ as organs similar to tracheæ; but I cannot admit that there is any real analogy between tracheæ and these organs, resembling each other, it is true, in their spiral turnings, but very different in their size, texture, and position. I persist, then, in believing that tracheæ are entirely absent from cellular plants.

Amongst those which we are obliged to refer to the class of vascular plants, tracheæ are wanting, according to Link, in *Lemna*, *Zostera*, *Ceratophyllum*, and *Najas*, all of them aquatic. Amici confirms their absence in *Najas minor*, but he is contradicted on this point by Pollini; and the absence of tracheæ in vascular plants is a fact which requires to be confirmed, especially since tracheæ not capable of being unrolled have been mentioned, and since there have been found true tracheæ in *Hippuris* and *Myriophyllum*, where it was at first believed that none existed.

Several anatomists, and in particular Wahlenberg, Rudolphi, &c., assure us that they have not found tracheæ in the Coniferæ, neither around the pith, in the leaves, in the younger branches, nor at the first development of the plant: this was found to be the case, according to them, in the anatomy of several species of Pines, Deals, Larch, Cedars, Thuja, and Cypress; but it was already known that true tracheæ exist in the young branches of the Juniper, &c. An anomaly so remarkable in the same family was difficult to be admitted: since then, Kieser, in a special treatise on the Coniferæ, has shown the existence of them, though they are more rare and more difficult to be seen than in other plants.

Oken thinks that tracheæ are analogous to the nerves of animals. This paradoxical opinion has not, that I am aware of, been admitted by any naturalist: it is thought to be founded on a simple hypothesis, viz. the sensibility of plants; but, even in admitting a nervous system in plants, it would be impossible to believe that it was represented by an organ which is found wanting precisely in those plants which bear the greatest resemblance to animals.

Section III.

Of Annular or Striped Vessels.

The vessels which I here designate (Pl. 2, fig. 1 *b, b,* 2 *a, a,* 5 *a, a.*) are those which Mirbel has described under the name of False Tracheæ *(fausses trachées),* Kieser under that of Spiral Annular Vessels *(vaisseaux spiraux annulaires),* and which I have often mentioned under that of Striped Vessels *(vaisseaux rayés).* Seen with the microscope, they commonly present the appearance of simple cylindrical tubes, marked with regular transverse parallel lines; when they are observed embedded in the tissue, they resemble true tracheæ which will not unroll; and they have often been described by the old anatomists under the name of *Tracheæ;* they differ from them, however—

1st, Because they do not unroll, and do not afford any trace of elasticity.

2d, Because their lines *(raies)* appear parallel, and not spiral.

3d, Because in the same plant they differ in diameter from the tracheæ.

Striped Vessels are found, in general, in the woody part of vascular plants; among Dicotyledons they are found in all the layers, except in the immediate envelope of the pith; in Monocotyledons they occur in each of the woody bundles; they are very abundant in the centre of the stem of the Lycopodiaceæ.

The largest annular vessels known are those in the stem of the Balsam.

Kieser considers these vessels to be composed of parallel rings, which, according to him, are of an analogous nature to the tissue of the tracheæ, and are capable, in certain cases, of gradually changing into spires (*Pl. 2, fig. 7 *b*,): these rings are sometimes, according to him, very slightly adherent to the membranous tubes formed by the walls of the neighbouring cellules.

Mirbel considers them to be tubes marked with parallel slits; others, as tubes provided with opaque parallel lines, which are of an analogous nature to the dots of dotted vessels.

Perhaps under the name of Annular Vessels *(vaisseaux rayés ou annulaires)* we really confound two different structures.

Section IV.

Of Dotted Vessels.

I include, with Treviranus, under the name of Dotted Vessels, *(vaisseaux ponctués, vasa punctata)* those which Mirbel calls Porous Tubes or Vessels, *(vaisseaux ou tubes poreux,)* and Kieser, Spiral Dotted Vessels, *(vaisseaux spiraux ponctues,)* Pl. 2, fig. 2 *b*, *b*, 5 *b*. Their ordinary state, under the microscope, is the form of a cylindrical tube, the walls of which present transverse series of opaque dots: they differ,

* From an excellent plate in Dr. Lindley's valuable "Introduction to Botany." 8vo. London, 1836.

then, from Striped Vessels, in having these dots separated from one another, and not joined in continuous lines; and from Strangulated Vessels, (of which we shall speak presently,) in their tube being cylindrical and not contracted at intervals.

These vessels are found abundantly among Dicotyledons, in the woody layers both of the root and of the stem and branches; among Monocotyledons, in the woody bundles: when they make part of a bundle of vessels, they are commonly situated in the side nearest the circumference of the stem. We are assured that they have also been found in the bark of Dicotyledons, but this fact is contested by more recent anatomists. The diameter of dotted vessels generally exceeds that of tracheæ and striped vessels; but this rule is liable to frequent exceptions.

Kieser considers dotted vessels to be formed of a trachea or annular vessel, of which the spires or rings are joined by a dotted membrane.

Mirbel, who first discovered these organs, does not admit the evidence of spires or rings in the formation of these vessels; but regards them as simple membranous tubes, marked with pores which are surrounded by a rim, giving them a dotted appearance.

Dutrochet also considers them as simple membranous tubes, marked, not with pores, but with dots caused by projecting vesicles.

As for my own observations, I have neither seen the spires nor the rings which Kieser admits in the structure of these vessels; but as I am of opinion that a negative observation cannot invalidate a positive one, when it is confirmed by all observers, I hesitate before I confirm their absence. At present I am disposed to consider these vessels as membranous tubes, marked with glandular dots.

Section V.

Of Strangulated Vessels.

The Strangulated Vessels (Pl. 2, fig. 6,) have been seen by Malpighi without his giving them much attention. Mirbel was the first who really called the attention of anatomists to the subject; and he has given them the name under which they are here designated. Treviranus described them under that of *Corps Vermiformes*. They are tubes marked with dots in transverse lines, as in Dotted Vessels, but contracted at intervals by transverse strangulations, more or less perceptible. Mirbel considers them as cellules, placed end to end, which supposes that there exist diaphragms which separate them: in following this opinion, it will be necessary to class them among the modifications of cellular tissue, and not among those of vascular tissue; but the existence of these diaphragms is very doubtful; the majority of anatomists deny it most positively. It appears that from considering these bodies as a series of cellules, Mirbel has been led to admit the existence of a dotted cellular tissue; but their analogy with dotted vessels is so strong, that it is impossible not to consider them either as modifications of these organs, or as very analogous organs. Kieser regards them as formed, like the preceding, by spires or rings very distant from each other, and connected by a dotted membrane.

Strangulated vessels are abundant in roots, articulations, joints, in branches and leaves at their first development, and, it is said, in natural or accidental warts.

Section VI.

Of Reticulated Vessels.

This form of vessel (Pl. 2, fig. 7 *a*,) is extremely rare in nature, and has been studied the least of all. Kieser has only discovered them in the Balsam and the Nasturtium (*Tropæolum*): he suspects their existence in other plants of a loose texture. According to this observer, these vessels are owing to the spiral or annular fibres which compose the tracheæ, or striped vessels, anastomosing unequally together, and leaving between them open spaces or oblong holes. They never attain, according to him, the size of dotted vessels, and are often ramified; they are more frequent in the root than in the stem.

Section VII.

General Considerations on the Structure of Vessels.

I have described, in the preceding sections, the usual forms which the vessels of plants present under the microscope; and I have intentionally avoided confusing these descriptions with any hypothetical or even theoretical ideas. It remains for us now to examine what are the modifications of which these forms are susceptible; and thence to deduce, if possible, the relation of these different vessels with one another, and their true nature.

Hedwig was the first to treat of these delicate questions in his Programme upon Vegetable Fibre: he thought that the turns of the spire of the tracheæ anastomosed together as they advanced in age, whence resulted the appearance of the annular vessel; then, if the junction continued to increase, the tube would take the appearance of a dotted vessel.

Rudolphi differs from Hedwig, for he regarded the tracheæ as simple spiral bands, which form a tube by their circumvolutions; but he considered that they gradually anastomosed, and thus changed into annular vessels. He affirms, in favour of his opinion, that he has found only spiral vessels in the young growing plants of *Alsine media, Caragana arborescens*, &c.

Mirbel, on the contrary, sets out with the principle, that vessels are a modification of the cellular tissue, and that they are formed of porous cellules: he believes that these cellules, placed end to end, form the strangulated vessels; and he seems to indicate, without expressly saying so, that these may change into porous vessels; that, by the near approximation of the pores, they become the vessels which he calls Slit Vessels (*vaisseaux fendus*), or False Tracheæ (*fausses tracheés*), which only differ from true tracheæ in being incapable of unrolling. He admits that all the intermediate states are found in nature; and that the same tube may, in different parts of its length, offer all these different forms: he calls this the Mixed Tube (*tube mixte*). But he thinks that each of these states of the vessels is primitive, and not produced by the act of vegetation.

Treviranus (probably in consequence of the idea originally thrown out by Sprengel) states as the effect of vegetation upon the vessels, that a course of things diametrically opposite ensues. He supposes that the granules which are observed in the cellular tissue, are so many organized vesicles, which, swelling up, form as many new cellules; that these cellules, according to their respective arrangement, form either the round cellular tissue, or the elongated cellules, or the cellules disposed necklace-like (*en chapelet*); that in this last state, the dilatation of the vesicles always continuing, the diaphragms break, and change the series of necklace-like cellules into dotted vessels, into false tracheæ (*fausses trachées*), and into true tracheæ, according to the degree of development. By this system, Treviranus explains how all the parts of a plant seem to derive their origin from the cellular tissue.

Kieser gives an entirely different opinion: he refers all this organization to an elastic fibre. When it is rolled spirally, it forms the trachea; when it is disposed in circular or parallel rings, it forms the striped or annular vessels; when the spires or rings are joined by a porous membrane, the result is the formation of dotted vessels; when these dotted vessels have their origin in the articulations, they are contracted at intervals, thus forming strangulated or necklace-like vessels (*vaisseaux en chapelet*); lastly, when the spires or rings are remote from one another, detached, or united in different degrees, the formation of reticulated vessels results.

I purposely pass over several other theories, which agree in different points with those which I have rapidly sketched out: an historical narrative of this subject may be found in Kieser's *Mémoire sur l'Organisation des Plantes*. What I have said is sufficient to show the extreme diversity of opinion entertained by anatomists, and the almost impossibility of having, in the present state of things, a satisfactory opinion upon points so refined.

The only idea which appears common to all these theories is, that all the different orders of vessels have the most intimate mutual relations, and can only be considered as modifications of one another; an opinion which is confirmed by this circumstance,—that all, or almost all the orders of vessels exist simultaneously in certain classes of plants, and are as regularly absent from others.

It is also confirmed by the extreme difficulty which most anatomists have encountered in distinguishing these orders of vessels with any certainty. Thus, for example, there are some observers, such as Dutrochet and Rudolphi, who admit the existence of tracheæ incapable of being unrolled; a state which, if it were well demonstrated, would seem to establish a kind of identity between tracheæ and annular vessels. Dutrochet particularly affirms, that when these vessels are subjected to boiling in nitric acid, we can destroy the junctions of their spires, and render them capable of being unrolled. Kieser remarks, that the rings of the vessels are often oblique; and that they are seen to pass by degrees, in the same vessel, into the form of true spires. The transition of annular vessels into dotted vessels has been pointed out and figured, by several of those who have thought that these dots, whatever may be their nature, being continued, form the transverse lines.

The analogy of dotted vessels with strangulated vessels is so great, that several observers have made little or no distinction between them.

It seems then admitted by observers, whether collectively or in detail, that all these different organs are only modifications of a single kind; but nevertheless, in commencing on this theoretical foundation, many doubtful points still remain to be examined. We proceed now to pass them in review, not for the purpose of solving them with certainty, but to show the contradictory tendencies, and the probabilities of the different opinions:—

1st. *Does each of these vessels, the structure of which* *we have described in the preceding chapters, preserve the same form throughout its entire length?*—The uncertainty on this subject has been caused by Mirbel, who admits the existence of mixed tubes *(tubes mixtes)*—that is to say, tubes which in different parts of their length may be dotted, striped, or spiral like a gun-screw. "The same tube," says he, "exhibits successively these different forms: a trachea of the stem may terminate at the root in a strangulated vessel—may become a false trachea at the knot at the base of a branch—may pass over this in the form of a dotted tube, and resume in the leaves or petals the form of a true trachea." Almost all the anatomists who have written since this opinion has been published, have written against it, or at least against its general application: several acknowledge that they find some tubes which bear at the same time short and long stripes, so that it may be perhaps admitted that annular and dotted vessels pass one into another, and in this very restricted sense the existence of mixed vessels may be admitted;—but the majority deny the other combinations. Rudolphi says, that he believes that it is impossible for an annular tube ever to change into a spiral vessel; and he explains the assertion of Mirbel, in thinking that he has, unconsciously, passed from one vessel to another under the field of the microscope. Dutrochet, in particular, affirms that there are no mixed vessels, in the sense which Mirbel assigns to this word; and that the tracheæ preserve their organization throughout their whole extent. Amici says, that he has never met with any vessels compounded of tracheæ and of tubes. The assertion of Mirbel, he adds, may perhaps be only a simple hypothesis: every one who has applied himself to the anatomy of plants, easily comprehends the impossibility of following the course of a vessel for so long a distance.

Kieser does not admit mixed vessels as a particular class; but he agrees much with the opinions of Mirbel in this,—that he admits the passage of one form into another. Thus, according to him, a tube may be partly a trachea, and partly an annular vessel, as he has represented in the Balsam; or partly a trachea, and partly a reticulated vessel, examples of which are found in the same plant. He thinks that, when they grow old, most tracheæ become dotted vessels, by the separation of the spires or the rings, and by the development of an intermediate dotted membrane: consequently, intermediate forms ought to be found from time to time between these two periods. Lastly, he affirms that all kinds of vessels become strangulated vessels at the articulations.

For my own part, I have not any theoretical objection to admitting transitions of form in the vessels; but I confess that I have never seen them but in an obscure manner, and one which has appeared to me doubtful, either for fear of passing from one tube to another under the field of the microscope without suspecting it, or because of the same difficulty which is also found in classing these different forms. I am inclined to think that these changes of form of one and the same tube have rather originated from theoretical ideas than been clearly seen by direct observation; and I venture still to direct observers to the verification of the facts.

2d. *Are vessels always simple, or do they ramify?*

This question is as difficult as the preceding, and equally merits the attention of observers. We find several figures of the old anatomists where the vessels appear ramified; but it is difficult to recognise, either in these figures or in the descriptions, whether they be in reality ramified vessels, or bundles of vessels which are distinct. Mirbel has most positively affirmed that tubes really branched do exist, and he has given a figure of them in his *Elemens*, Pl. 10, fig. 9. Kieser adopts the same opinion, at least with regard to the reticulated vessels; and represents them ramified *(Mémoire Org.*, Pl. 11, fig. 51; and Pl. 12, figs. 56, 57*)*, but respecting the other kinds he does not say it is the case; however, he appears not to doubt the possibility of this ramification. It is certain that it is very rare: if it really does occur, it is perhaps only in the articulations; and as this is the part in plants where the usual interlacement of the fibres renders the observation very difficult, there remains some doubt about those ramifications, which, however, probably do exist. Still, even in admitting the appearances represented by Kieser, must we not well distinguish whether he does not really examine new vessels which are united with the old, or vessels which, being enclosed in one sheath, tend to diverge at their exit?

3d. *Do the different kinds of vessels which we have enumerated preserve the same form during the whole period of their existence?*

If the same tube could be examined at different periods of its existence, this question would be susceptible of solution in a direct manner; but as this observation is impossible, we must have recourse to other means of solving it.

Those who think that the trachea is the original form of all the other vessels, rest their theory upon facts striking enough—viz. that tracheæ exist, both in young plants and young shoots, more abundantly in proportion than other vessels; and consequently it is probable that these other vessels are no more than transformed tracheæ. Kieser, in particular, has given great weight to this opinion by his dissections of the Gourd at different ages. In admitting the truth of the fact, we nevertheless cannot deny that there are others quite as positively affirmed, and from which one must draw an opposite conclusion. Thus it is certain, that the first woody layer of trees contains tracheæ in a state incapable of unrolling, even in aged stems; and that they have not been found in the next layers, even in a young state.

Those who derive the origin of vessels from the cellular tissue, support their opinion, 1st, upon this,—that in the vegetable kingdom the cellular tissue is the most universal texture, and that it alone composes those plants which appear the least perfect; 2d, that in every plant it is more abundant in the individual or its organs at the time of their first development, than at an advanced age. The first of these proofs appears to me to be deduced from an inadmissible description of reasoning—viz. the plan of considering the vegetable kingdom as an individual plant, and of deciding upon one species and one class from another, as if the general forms of beings were endowed with immutability. As for the second, the point is true; but it is as easily explained by supposing that the development of vessels is a little slower than that of the cellules.

Lastly. There is a third class of anatomists who regard all the forms of vessels as constant, and who assert that age does not determine the forms under which the different orders of vessels have been established. But even these give credit to the incrustation of the cellules of the wood and bark, to the formation of an analogous incrustation, or a development of a peculiar cellular tissue in the aged vessels: and it must be confessed that their principal argument is purely negative; that is to say, that it relies upon the fact, that none of the changes admitted in the different theories have ever been demonstrated by direct observation.

4th. *What is the nature of the markings which are observed on the dotted and strangulated vessels?* This question merits an attentive observation, seeing that it is very closely connected both with the ideas which we must form of the nature of vessels in general, and of their use.

Mirbel, who first described with care these two kinds of vessels, affirms that these marks are pores or holes, commonly bordered by an opaque raised rim. He says, in his *Anatomie*, tom. i. p. 57, that these pores are not the 300th of a line in diameter; then, in his last work, he reduces their diameter to nearly a third of that which he first estimated them at, in saying that they are perhaps not the 300th of a millimetre. He considers the transverse lines of the annular vessels as a series of closely approximated pores, and, consequently, as actual slits. This opinion appears to have been admitted by Bernhardi; and it is moreover maintained by Amici, who gives a figure of these transverse slits (*Observ. Micr.* fig. 31, 32). Kieser, although advocating a theory quite opposed to that of Mirbel, admits likewise—1st, that the marks of dotted vessels are true pores, the orifices of which he has seen in the Sassafras, the French Bean, and the Oak. 2d, That the reticulated vessels present actual holes formed by the incomplete junction of the spires. Likewise he agrees with Mirbel upon the first point, but differs widely from him in the second. That which Amici says of the slits of the vessels, appears to relate rather to the reticulated vessels of Kieser than to striped vessels.

On the other hand we find a great number of anatomists who deny the perforation of the marks of dotted vessels. I have myself been induced by microscopic observation to doubt the perforation of these organs, and to believe that that which has been considered a pore is a luminous spot, such as is seen in the bubbles of air which are found in water in the field of the microscope. As early as 1813, I proposed, in the *Théorie Elémentaire*, to give to the tissue the names of dotted (*ponctué*) and striped (*rayé*), instead of those of porous (*poreux*) and slit (*fendu*), which Mirbel had established: my intention was not to affirm any thing in addition to what is proved; and these names have in fact the advantage of being admissible under all theories. More lately, Dutrochet has given new proofs of the non-perforation of the dots and lines: he considers the dots to be little globular bodies filled with a greenish transparent matter; he has observed that they become opaque by nitric acid, and that then their centre no longer transmits light: he adds that caustic potass restores their transparency, that there are certainly no visible pores, and that the doctrine of Mirbel is doubtful from the sole fact of the size which he has attributed to them.

If we admit that the markings of vessels are not perforated bodies, we must seek farther in order to discover their nature. Rudolphi and Link regard them as amylaceous or mucilaginous granules. Treviranus appears to consider them as young cellules, destined to increase in size and to become themselves distinct cellules. Dutrochet (considering that they undergo the same changes under the action of acids and alkalies as the globules of the nervous system of animals—that is to say, that they are insoluble in the first, and soluble in the latter, knowing that the animals most nearly related to plants have a nervous system always less concentrated, and seeing that these markings exist in sufficiently great abundance in the vegetable organs which perform any movement,) has believed that they may be considered as the widely spread elements of a diffuse nervous system; and he has proposed to call them nervous corpuscules (*corpuscules nerveux*), meaning by this term a globular microscopic cellule filled with nervous substance.

Although there certainly exist facts which prove that vegetable life differs less than has been believed from animal life, and although in particular the recent experiments of Marcet and Macaire tend to give more probability to the existence of a nervous system in plants, I must confess that I am still far from affirming that vegetables have a nervous system, or, even admitting it, that these corpuscules perform this function. In fact, they are absent in most of the plants which most resemble animals, such as the Algæ and Fungi, and they are found in abundance in those where one would least suspect spontaneous motion, as the Lycopodiaceæ. I am disposed to consider these corpuscules as little glands, destined to co-operate in the nutrition, and perhaps at the same time in the transmission, of the juices of one cellule or one tube to the neighbouring cavity. All the physiological arguments, by which one would establish the existence of pores or slits, are deduced from the necessity of the transmission of the juices, and should be applicable to this opinion; but I only present it as a simple hypothesis which seems to me probable; and without admitting either visible pores or spongy glands, I do not deny that the membranous tissue cannot be endued with an hygroscopic porosity sufficient to transmit the juices. There is little doubt that different vegetable membranes, which appear homogeneous under the strongest microscopes, are endowed with the faculty of differently elaborating the juices; but, although the diversity of results is evident, we have too much difficulty in isolating the juices furnished by each kind of cellules or vessels, to affirm any thing of their nature.

5. *What is the affinity of the vessels with the neighbouring cellular tissue?*

This question will be one of the most important to resolve, in order to understand the use of the vessels, but it is unfortunately one of the most difficult parts of the subject. It may be divided into two—the *termination* of vessels, and their *juxtaposition.*

We have said, in speaking of the Tracheæ in particular, that some think that they are lost in the Cellular Tissue, and others, that they go to meet the pores of the Stomata. These two opinions can be sustained in all kinds of vessels except in the strangulated, which are limited to the articulations; but no one has hitherto seen in a clear manner either the origin or the termination of a vessel, and this is a point to which it is important to call the attention of observers.

As to the position of the vessels in the tissue, it is certain that they are always surrounded by elongated cellules usually close to one another. But have they any communication with the intercellular passages? Do the walls of the cellules themselves bear any part in the construction of the different kinds of vessels? These questions appear to me to be still without a precise answer.

Section VIII.

On the Use of the Vessels.

If we are far from agreeing upon the structure of the vessels of plants, we must expect to find still more difference, if possible, in the opinions relative to the use of these organs.

The only point upon which observers are agreed, is that the vessels do not contain any Proper Juice. Kieser certainly found it once, but he considered it as an accidental extravasation.

It is also pretty certain that the vessels do not contain the sap elaborated by the leaves, since they are for the most part absent in the bark, which is the part of plants where these elaborated juices pass in the greatest quantity.

The question then is reduced to this—Whether these vessels usually, or by turns, conduct either the air, or the lymph or unelaborated sap. That the vessels contain air, appears to me to be shown by reasoning and observation. 1. Since vessels only exist in plants which have stomata, and as the stomata are orifices open to the air, it is probable that the use of vessels is in connexion with the air. 2. Most observers affirm that the vessels have appeared to them to be void of all liquid, or, in other terms, to be full of air. 3. All those vessels which are perforated or slit (and we have seen that in certain theories all are so more or less) are very imperfect conductors of fluid.

On the other hand, those who pretend that the vessels serve to carry the fluids, depend upon the following facts :—

1. In experiments where a plant has been compelled to draw up a coloured fluid, we see clearly enough that the walls of the vessels become coloured. I have seen it very distinctly, especially in the annular vessels of plants with a loose tissue. But it must be remarked that the fact has only been well observed in the case where a stem has been cut and the end plunged into coloured water, consequently in circumstances slightly different from the natural course of things; and that in observations so delicate, it is impossible to distinguish if the colouring takes place in the interior or exterior, that is

to say, in the intercellular passages: though I incline to the first opinion, yet I do not regard it as demonstrated.

2. In microscopic observations it is not rare to see bubbles of air in certain vessels, especially in the annular or dotted; but a bubble of air is only visible when the rest of the cavity is full of fluid.

3. In the hypothesis that the vessels meet the stomata, and that the stomata serve for the evaporation of the water, it must be concluded that the vessels contain it also.

4. In the opinion of those who deny the existence of intercellular canals, it is almost necessary to admit that the lymph passes in the vessels; and this is also the opinion maintained by Mirbel and Dutrochet, whilst the contrary opinion is defended by Kieser and Amici, who admit the existence of intercellular canals.

It seems then that the theoretical ideas upon the general structure of plants have more influence than direct observation upon the conjectures which are made of the use of the vessels. Among these contradictory arguments, it is without doubt difficult to arrive at a final opinion; however, the great analogy which vessels bear to one another, the probability of their transformation from one into the other, do not permit us to think that their use can be very different; but, as the trachea in particular appears evidently an aerial canal, I am inclined to believe that all the other vessels perform the same office. When a stem with a loose tissue is cut transversely, the juice is never seen to exude from the orifice of the vessels, but always from the cellular tissue; bubbles of air, on the contrary, are often seen to proceed from them. I think then, definitely, with Kieser, that the vessels are aerial canals; but I do not mean to deny that, in some particular cases of vegetation, they may serve for the passage of the lymph, in conjunction with the intercellular passages.

The ascent of the lymph in the stems of Mosses and Hepaticæ, or in the peduncles of Fungi, which have no vessels, is a great argument for believing that the vessels in their ordinary state are not the conductors of the lymph; and this comparison tends to confirm the preceding opinion.

CHAPTER IV.

OF THE FIBRES AND WOODY LAYERS.

When a stem of a vascular plant is cut transversely, we observe a certain number of points more compact than the rest of the tissue; if it be cleft lengthways, we do not fail to remark that these points are the ends of so many longitudinal bundles, which separate more easily from the rest of the tissue without being broken; these bundles bear the name of Fibres, *(fibræ.)*

If we examine them with the microscope we easily perceive that a fibre is not a simple organ, but that it is composed of bundles of vessels intermixed and surrounded by elongated cellular tissue. In common practice, when it is wished to procure the fibres of plants isolated, the plants are placed in water to macerate, and after some time the fibres seem to separate spontaneously; this is what constitutes the maceration of Hemp, Flax, *Agave*, *Phormium*, &c. But this operation in reality disorganizes the vegetable tissue; in fact, it exposes to the action of the water a tissue composed of parts which are capable of being altered in different degrees by that liquid: the water first affects the softer and less compact parts—viz. the regular cellular tissue; and by it separates the fibrous bundles which are really joined or continuous with the cellular tissue. If the operation be continued, the water affects a part of the elongated cellular tissue interposed between the fibres, and each fibre is divided into several fibrillæ: if the maceration be still pursued, the vessels themselves are disunited, and only a homogeneous paste is obtained, such as is seen in the manufacture of paper. The analysis of this popular operation shows how the anatomists of old were deceived when they thought that maceration was a good means of knowing the intimate structure of vegetables; it is, on the contrary, a proceeding eminently defective, since it only acts by destroying the more delicate parts.

The way in which I have represented the structure of fibres, explains very well why they are, even without maceration, more difficult to break transversely than to split longitudinally, or to separate from the neighbouring cellular tissue. In breaking a fibre transversely, it must destroy the walls of a number of cellules; whilst, in a longitudinal direction, we only meet with now and then the partitions which terminate the tubular cellules. This is the reason why all the fibrous parts of plants are more easily split longitudinally than transversely; this is what workmen call, to follow *the grain.* Parenchymatous parts, on the contrary, may be broken indifferently in all directions, because they are composed of regular cellular tissue.

The different tenacity of the fibres of plants, results —1st, from the nature itself of the membranous tissue; 2dly, from the number and compactness of the molecules which are there deposited; 3dly, from the number of the vessels and tubular cellules of which each bundle is composed; 4thly, from the degree of elongation of the tubular cellules. The most tenacious fibres which are known, are those of the *Phormium tenax,* called, very improperly, New Zealand Flax. This tenacity has been measured by Labillardière, by suspending weights to filaments of a fixed diameter; by this method he found that a thread of silk could support a weight of 34, *Phormium tenax* $23\frac{4}{5}$, Hemp $16\frac{1}{3}$, Flax $11\frac{3}{4}$, and Aloe, or the *Agave Americana*, 7.

We often use the word *fibre* as a convenient abbreviation to express a bundle composed, in vascular parts, of vessels and elongated cellules, and, by analogy, in cellular parts, simply of elongated cellules—forming a bundle distinguished from the rest of the tissue by its greater tenacity. The veins of leaves are only fibres more or less ramified, which, in separating from one another, leave in the cellular tissue interposed between them, a space for its development.

Dutrochet gives to the name Fibre a sense a little different from the preceding: he says, that it is a rectilinear assemblage of articulated cellules, or of elongated cellular tissue; he adds, that these cellules are extremely small; that, therefore, Fibres are modifications of the cellular tissue, constituting distinct organs, which draw up coloured water, and convey the sap. This definition of Dutrochet would apply well enough to the veins or fibres of cellular plants; but it has always appeared to me, (and I believe that I am in accordance with all other observers,) that the fibre of vascular plants is composed of vessels and cellules intermixed.

It suffices for the present to conclude that a Fibre is not a simple organ, but a bundle composed, in the majority of cases, of vessels and elongated cellules firmly united into bundles; or solely of elongated cellules. It is in the longitudinal direction of the fibres that the course of the juices, especially the ascending, is directed.

When several fibres are distributed circularly around an axis, either real or ideal, the collection of them bears the name of Layer, *(stratum.)* The layers are generally concentric rings, or cones, placed one upon another; they are far from being simple organs, since they are formed not only of fibres, which are themselves compound, but also of cellular tissue more or less abundant, which separates and connects, either the fibres of the same layer, or the layers themselves. I shall return to the Woody and Cortical Layers, in speaking of Stems; and I only mention them here to avoid confounding them with the elementary organs.

CHAPTER V.

OF THE CUTICLE AND EPIDERMIS.

SECTION I.—*General Considerations.*

THE name of CUTICLE, or EPIDERMIS, has been given to that thin transparent membrane which covers the surface of plants, and which is more or less easily separated from the rest of the tissue. Two very opposite opinions have been advanced upon the nature of the Epidermis; the one (and Grew appears to be the first who maintained it) admits that it is a membrane, properly so called, distinct from the tissue, which it covers; and that it increases with the plant, as the skin of animals. The others (and Malpighi may be considered as the author of this theory) have maintained that the epidermis was only the external cellules of the plant, or, at least, their outer wall become more solid by the action of the air and light, by the passage of the juices, and by the effect of evaporation. The partizans of the first opinion maintain that the opaque reticulated lines which are seen on the epidermis, are vessels which form part of, or adhere to it; these Hedwig has named *Vasa lymphatica cuticulæ*. The partizans of the second, think, on the contrary, that the lines are traces of the walls of the cellules broken by raising the epidermis. Hedwig, Kieser, and Amici, among the moderns, have maintained the first opinion. Kroker, Mirbel, Link, Sprengel, and Rudolphi, have more or less adopted the second; and I have myself coincided with them in my former works. From new observations, and a more attentive regard to known facts, I have been led to the idea that the two theories are both quite true, but applicable to different organs; and that all the contradictory arguments of anatomists are true as concerns one part of the organs, but false with regard to the other.

I admit, then, that the epidermis of leaves, and most probably that of all annual shoots, is not a peculiar membrane, (as Grew, who called it *Cuticle*, considered,) but a particular layer of cellular tissue very distinct from all the following, constituting also a kind of covering which I also call CUTICLE; for the name Epidermis, which signifies a scarf-skin, does not apply to it, since it constitutes of itself the entire skin: on the contrary, in old stems, the membrane, or membranes, which are formed upon the bark, are only the external cellules dried by the air; these may retain the name EPIDERMIS, since the cellular envelope, which is beneath, performs, in certain respects, the function of the skin.

In examining these two organs, we shall at once give both their description and the causes of our opinion; and, consequently, we shall discuss the reasonings for and against the two theories.

Section II.

Of the Cuticle, properly so called.

When the pellicle which covers the leaves is raised, we see that it is a very fine membrane, marked with spaces, varying in form in different plants, and often in different parts of the same plant.

Those who pretend that this pellicle is the external wall of the common cellules of the leaf, rely upon the following facts:—

1st. It cannot be raised without tearing at the same time the tissue of the cellules, and exposing a part of the juices.

2d. The spaces on this pellicle are forms which bear a more or less distinct analogy, either with those of the cellules of the plant, or with those of the organ from which the cuticle has been raised; thus the cellules of Grasses, and those of petioles, are in the form of an elongated parallelogram, like the spaces of the cuticle which covers them.

Those, on the contrary, who maintain that the cuticle is a peculiar membrane, marked with spaces by network, which is not produced by the edges of the broken cellules, remark—

1st. That the denudation of the parenchyma of a leaf, by the removal of the cuticle, is better explained by supposing that the walls of the cellules adhere to the cuticle, than by supposing that the two bodies are only one.

2d. That if all the spaces on the cuticle were always of the same form as the subjacent cellules, one might believe that they were owing to their rupture; but it is not so. A great number of leaves have the cuticle marked with spaces, the borders of which are irregularly wavy, and of forms which do not correspond with the cellules of the same plant, (Pl. 3. Fig. 1.) Those, also, which present hexagonal forms, differ in size, or other circumstances, from the cellules of the plant. Amici has given several examples which confirm this mode of reasoning; and I have myself seen this fact in different plants, and, in particular, in *Tritoma Uvaria*, (Pl. 3, Fig. 4.)

3d. The cuticle of almost all leaves presents here and there pores, which are called *Stomata;* their form is very remarkable, and they do not exist on the membranous pellicles which are formed on the parenchyma when the cuticle has been removed: but, if this were only the external wall of the cellules dried by the air, we do not see, on the one hand, how the stomata could be formed in the primitive cuticle, or, on the other hand, why they could not be formed a second time, as the first.

4th. Keith, who has studied this subject, remarks, that the cuticle exists in organs protected from the action of the air,—as the internal parts of buds, where one cannot conceive its existence by the theory of Mirbel.

5th. The same author also remarks, that the cuticle of leaves is never reproduced when it is taken off; which would happen if it were formed by the action of the air upon the cellular tissue.

It results from all these facts, equally true, that the cuticle of leaves appears to be formed of a layer of cellules, usually differing in form, and various other circumstances, from those of the common parenchyma; and that it may on this account be considered as a kind of peculiar membrane, independent of the subjacent cellular tissue;—that when it is removed by tearing it, the external wall of the cuticular cellules is only obtained;—that the lines which are observed on it are the traces of cellules, sometimes very different from the ordinary ones, and sometimes very much resembling them;—lastly, that it can only be completely seen by a transverse section of the leaf. The same reasonings are so clearly applied to the cuticle of petioles, young branches, the calyx, corolla, fruit, and, in general, of all the organs examined in the state of their first development, that I do not know how to admit another opinion. We shall see presently that old trunks present entirely different phenomena.

Let us examine, for the present, the Cuticle, considered as a peculiar membrane.

The Cuticle does not appear to be a simple membrane, as it seems from a common inspection, or even under most microscopes, when it is removed from the surface of the leaf; but it appears formed of a row of flattened cellules, distinct from those of the parenchyma, as Amici has distinguished by the aid of his powerful microscope, and as I have seen in *Tritoma Uvaria* with weaker instruments.

This membrane is generally more tenacious and compact than that of the ordinary cellules of the parenchyma; which may result either from its peculiar nature, or from the action of the air, light, or evaporation: this last cause appears to be the principal; for—

1st. The cuticle is much more compact when it has been some time exposed to the air, than when it is first developed; wherefore it has been said of certain very fugacious organs, that they are devoid of cuticle.

2d. The cuticle, furnished with stomata, is generally more compact, and, consequently, more easily separable from the subjacent tissue, than that which has none, and which appears less endowed with the faculty of evaporation.

3d. We know that the water which arrives at the surface is charged with earthy particles which it deposits, where it is evaporated; and that, in consequence, the membrane where the evaporation takes place must become denser.

The cuticle is naturally transparent, and nearly white; all the colours of the leaves, branches, and flowers, are due to the nature of the substances contained in the parenchyma; the cuticle, however, slightly influences the colouring, either by the degree of its transparency, or by its adhesion being more or less strong with the cellular tissue, or, perhaps, also, by the white or yellowish tints it gives to some species. It influences, also, by its peculiar nature, the smooth or rough appearance of the organs.

At the time when an organ begins to be exposed to the air, the cuticle usually presents then all the stomata and hairs which it is accustomed to bear; they are, consequently, very close to one another, and as the surface increases, they become more distant; wherefore old leaves are, in proportion, less hairy than those which are young. This effect is also due, in several cases, to the natural fall of the hairs.

When the cuticle is observed with a microscope, or strong lens, we see a network of lines which form the spaces, either parallelogram-shaped, as in the Narcissus and the Oat, or angular, as in the Lily, or curiously waving, as in *Ranunculus repens*, and *Galium aparine*. These lines often resemble simple threads; they also frequently appear double; whence we presume that they are hollow, and form a system of cuticular vessels. Hedwig, Kieser, and Amici, maintained this opinion, contrary to that of many other anatomists. It is believed that these vessels serve for evaporating the water; but they exist in almost the same number on the surfaces which evaporate very little, as on those which evaporate much.

There is great diversity among plants of different species, and among the organs of the same plant, with regard to the facility with which we can raise the continuous pellicle formed by the external wall of the cellules: in general, that of the lower surface of leaves can be detached more easily than that of the upper; that of leaves of an herbaceous or fleshy tissue, more easily than that of dry and woody ones; that of foliaceous parts, more than that of the sexual or petaloid; that of surfaces furnished with stomata, than that where they are absent; that of organs exposed to the air, than that of those which are submerged or subterranean; that of smooth or slightly downy surfaces, than that of those abundantly covered with hair, &c. The various combinations of all these elements, determine the numerous and easily comprehended differences between all plants.

Section III.

Of the Epidermis of Old Trunks.

As soon as a young shoot has attained its natural size, it ceases to increase in length, and commences to expand, following the laws which we will hereafter examine. The primitive cuticle, which has fulfilled for a certain time the function for which it was destined, and which is not destroyed by the fall of the organ, as happens in the case of leaves, flowers and fruits,—the cuticle, I say, of the branches or living stems is found in a particular state: it becomes at first a little opaque; then dries up, exfoliates, or cracks, either from the continuance of the evaporation and the action of the air, or by the distention which the enlargement of the trunk produces; it is then destroyed entirely, or in part; and, if we except some fleshy stems which grow slowly, the pellicle which covers the branches of the second or third year presents an appearance different from the cuticle; it is of a closer tissue, and offers in general a greater thickness.

This new membrane evidently appears formed, as Malpighi thought, of the external cellules of the cellular tissue, which, being dried by the action of the air, become flaccid, and take a membranous appearance. It is this membrane, sometimes simple, sometimes complex, which bears the name of the Epidermis of Trunks (*épiderme des troncs*), or the Epidermis, properly so called. Du Petit Thouars, who, in his fifth *Essai sur la Végétation*, has well elucidated the formation of the epidermis, remarks, that it would be almost impossible, in every other hypothesis, to conceive the enormous increase which a membrane ought to undergo, which would be supposed the same at the first development of a tree as at an advanced age. The epidermis is simple when the row, or rather the external layer of cellules, is alone dried; it is double, triple, or multiple, when several rows of cellules are successively dried: this is seen, for example, in a very high degree, in a Peruvian tree, which Ulloa has called *Quinales*, and of which he says, that having detached more than 150 layers of the epidermis, he had no patience to count more, not having reached the middle of the bark. We can see an analogous circumstance in our White Birch, a branch of which, at its first development, has a cuticle; then it takes a true epidermis; then, as it advances in age, it takes two, three, and even fifteen or eighteen; and at last finishes by having the bark cracked so as to present interrupted plates of white epidermis on the shreds of its cellular envelope. It happens thus in all trees, that after the time when the transverse distension has favoured the formation of an epidermis, it is succeeded by another, when, from the same cause, the epidermis is destroyed by the cracks of the bark.

It is the cuticle which always bears either the stomata, which are only seen well by the microscope, or the hairs which so often cover the surfaces of leaves: of both these we shall speak very shortly. We are obliged to mention them here for the purpose of remarking, that when the cuticle is destroyed, these organs likewise are. The epidermis, properly so called, which is formed by the drying up of the cellular tissue, never bears either hairs or stomata. This circumstance tends to confirm the difference between these two membranes, hitherto confounded under a common denomination.

The cuticle of young branches has a tendency, in general, to tear, separate, or detach itself in a longitudinal direction, which is that of its growth; but when the elongation has ceased, and as the increase in diameter becomes perceptible, the cellules, which upon drying form the epidermis, are drawn in a transverse direction, so that instead of being elongated longitudinally as they were at first, they become so transversely: it results, therefore, that they are more easy to break across than lengthways, for they present in this direction fewer partitions than in the other; thus the same reason which makes all organs which increase in length, more easy to be split in a longitudinal direction, causes the epidermis, which is distended transversely, more easy to be split in a transverse direction; so that the epidermis of the Birch, Cherry, and generally of all smooth trunks, divides nearly circularly across. In trunks marked with channels and longitudinal canals, as the Vine, the epidermis preserves, on account of its longitudinal inequalities, the property of splitting lengthways. In tubercles, exostoses, and generally in all round parts, and where the growth is in all directions, the facility of rupturing or splitting the epidermis is likewise equal in all directions.

I have given the name of LENTICELS (*Lenticelles*) to certain little oval spots which are seen on the bark of several trees, especially of the Birch: their use and history will be the object of one of the following chapters; but I mention them here because they may serve to verify all that I have said. In their young state they are oval longitudinally; by degrees they become round, on account of the thickening of the branch; and they finish by elongating transversely. The cuticle or epidermis of the branch, of which these organs form part, must undergo the same modifications as regards the form of its cellules.

The use of the epidermis on trunks must be, in general, to protect the cellular envelope: this is performed, according to circumstances, in three ways:—

1st. The epidermis stops or diminishes the evaporation; and the absence of all evaporating pores in this membrane sufficiently explains the cause.

2d. The epidermis opposes the decomposition which would be caused by the external humidity: the earthy, and frequently even silicious nature of this membrane, perfectly gives the reason of this result.

3d. The epidermis may also, in some cases, prevent the frost from reaching the bark. This last effect is especially observed in trees, the epidermes of which are numerous: each of them retains a layer of enclosed air; and they form so many envelopes, which prevent the bark from acquiring an equilibrium of temperature with the circumambient air.

Thus the Birch, which has more epidermes than any other European tree, ascends highest upon the Alps, and reaches nearest the frozen regions of the pole.

CHAPTER VI.

OF THE STOMATA, OR PORES OF THE CUTICLE.

I DESIGNATE, with Link, under the name of STOMATA *(stomates)*, the oval orifices, which are very visible under the microscope, in the cuticle of the largest part of the herbaceous surfaces of plants.

Grew was the first anatomist who observed them; but he did not call them by any particular name, or bestow any great attention upon them. Guettard, who only saw them with a lens, has called them Miliary Glands *(glandes miliaires)*. Gleichen observed them well on Ferns, but he took them for the male organs. Hor. Bénéd. De Saussure calls them Cortical Glands *(glandulæ corticales)*. Hedwig designates them by the names of Evaporating Pores, *(spiracula, pori exhalantes)*; Jurine, Link, and Kieser, by the simple name of *Pores*; De La Metherie, by that of Epidermal Glands *(glandes epidermoïdales)*. Mirbel has called them, in different works, Elongated or Large Pores *(pores alongés ou grands)*. Rudolphi has given a good description of them under the name of the Pores of the Epidermis *(pores de l'épiderme)*. I have myself mentioned them under the name of Cortical Pores *(pori corticales; pores corticaux).* But as neither of these compound names is strictly exact, and as a simple term is more convenient, I prefer, now, to designate them by the name of STOMATA, which Link has given them. I prefer it to that of *Pores,* which is employed in very different senses, for designating every kind of little orifice.

The Stomata present themselves under the form of oval pores, sometimes almost round, at others rather elongated. Their size, which varies in different plants, is commonly in accordance with the meshes marked on the cuticle. Liliaceous plants, and in general those of a loose tissue, have them commonly larger and fewer; those of a more compact tissue have them smaller, and nearer one another. The open orifice of the stomata has been seen and unanimously admitted by all observers, except Mirbel, who, after having admitted and figured it in his first works, supposes (I know not what foundation he has for so doing) that this orifice is an optical illusion. One may especially observe the porosity of the stomata in this,—that their orifice is equally seen, whether the inferior or superior surface of the cuticle be observed. Not only do all other anatomists admit that the stomata are really perforated, but that the openings vary in size according to circumstances: they are, in general, open in leaves which grow well, and in parts exposed to the sun; they are less open, or sometimes entirely closed, on the surfaces of leaves which are very old, or which have not been exposed to the light for some time. Their border has the appearance of a kind of oval sphincter, capable of being opened and closed: the line which surrounds this sphincter is always continuous with those which form the network of the cuticle: under this, and in the interval between the border of the sphincter and the pore, granules of a green matter are very frequently found.

Stomata exist in a more or less distinct manner in all the foliaceous surfaces of vascular plants—viz. in leaves properly so called, in stipules, in the green bark, in the calyx, and pericarps which are not fleshy; they are wanting in all buds, aged stems, petioles which are not foliaceous, most petals, fleshy fruits, and all seeds of vascular plants; they are also absent in all the organs of cellular plants. Some naturalists, and especially Treviranus, affirm however that they have seen them in a small number of Mosses; but I have never remarked them. Rudolphi also denies their existence in Mosses and Hepaticæ.

Leaves do not bear stomata indifferently on both surfaces: some, as for example those of the Pear, *Begonia spatulata*, &c. have them only on the inferior surface; most liliaceous plants and grasses have them on both surfaces; in the floating leaves of the Nymphæacea they are found only on the superior surface. Rudolphi affirms that they are entirely wanting in some extraordinarily woolly leaves, such as those of *Marrubium*. They are only found on petioles when they are dilated so as to form a kind of leaf, or when they are surrounded by foliaceous borders. The stipules have them only when they are foliaceous; this is also the case with young shoots, which only have stomata when they are green, soft, and herbaceous; and they are generally absent when they are either very woody, fleshy, or membranous; some woody stems, with a green bark of almost a foliaceous nature, have stomata as true leaves have—such as, for example, those of *Ephedra*.

The involucrum and calyx follow analogous laws; they have stomata when they are foliaceous, and scarcely, if ever, when they are membranous. Perigones have them almost entirely on their lower surface, even when they are coloured, as in the Marvel of Peru *(Mirabilis)*, and they are most frequently wanting on the superior surface; they are very rarely found in the petals, except in some plants, such as *Michauxia*, *Campanula barbata*, *Peganum harmala*, which have them externally; *Dictamnus albus*, and, according to Rudolphi, *Epilobium angustifolium*, present them on both surfaces. I have found them on the inferior surface of petals, which have been transformed into leaves, in a monstrosity of *Ranunculus philonotis*. I have never seen them on the styles or stamens; but Rudolphi asserts that they exist on some, such as those of *Lilium bulbiferum*. They are often found on pericarps which are of a foliaceous nature; but all that are fleshy are, without exception, devoid of them.

This last law is analogous to that which is observed in leaves; those which are fleshy have much fewer, in proportion, than those of a thin or fibrous texture. In all these different organs we never find stomata, either on the primary or secondary veins, or on their ramifications, but always on the parenchyma properly so called. This position of the stomata is contrary to that of the hairs, which spring from the veins or their ramifications.

The stomata are, in general, scattered over the parenchyma, and distributed at nearly equal distances; sometimes, as is seen in leaves with parallel veins, they are disposed in one or two longitudinal rows between the veins. Those of the *Equisetum*, observed by Vaucher, are disposed upon the stem in longitudinal lines, between the projecting veins; their number and disposition would even furnish good specific characters.

There are some leaves where they are found congregated here and there, forming kinds of little rosettes or round spots. These rosettes are visible on the inferior surface of the leaves of *Begonia spatulata*, forming little dots, which are visible to the eye; they are especially very remarkable in the leaves of *Crassula cordata* and *C. arborescens;* for the round dots which are seen by the naked eye, are the collections of stomata. This fact made me formerly suggest the idea that the stomata might be the orifices of the vessels; for each of the dots of the *Crassulas,* which I have just mentioned, is the termination of a fibre which is itself a bundle of vessels. I was confirmed in this idea, from considering that the stomata are not present in plants devoid of vessels; I confessed, however, that I never saw the continuation of a vessel to one. Comparetti has gone farther than I have, and has asserted that he has seen vessels terminate in stomata. Mirbel says, on the contrary, that the stomata are the orifices of cellules; and Kieser considers them as the terminations of the intercellular canals. I incline, now, to this last opinion; but it is a question which deserves fresh examination.

The stomata are absent in several plants, on account, it seems, of their manner of living. Thus—1st, They are not found either on the leaves or stems of plants which grow under water, such as *Zostera, Ceratophyllum,* &c.; and in those which have part of their organs under and part above water, as several species of *Potamogeton, Myriophyllum, Nymphæa,* &c. the stomata exist only in the parts exposed to the air; they are found on the leaves of *Ranunculus aquatilis* when they are raised above the water, but are wanting when they grow under it. 2dly, The part of the leaves of bulbous plants which is concealed in the Onion, and consequently etiolated, is either entirely deprived of them, or presents some closed and imperfect ones. All truly parasitical vascular plants, which are not of a green colour, have no stomata either on their stems, or on the imperfect rudiments of their scale-like leaves; such as *Orobanche, Lathræa, Monotropa, Cuscuta*, &c.; on the contrary, those which are green, as the Misseltoe (*Viscus*), and *Loranthus*, are abundantly supplied with them.

The use of the stomata is an important point in vegetable physiology and anatomy, and naturalists have formed different opinions with regard to it. Perhaps these organs can, under different circumstances, perform different offices. Some have attributed to them the office of exuding the resinous or waxy matter which covers different leaves; but when we consider the universality of the stomata among vascular plants, and the rarity of these excretions, we are compelled to conclude that if the stomata serve for their formation or production, this can only be regarded as an additional use of these organs. As for the cerous matter which forms the glaucous dust of plants, it offers a second objection; it exists on several fruits, such as plums, for example, which have no stomata.

It is among the general functions of the foliaceous organs that we must look for the office of the stomata; these orifices may then serve either for the exhalation or the absorption of the air, or for the exhalation or absorption of water.

As for their connexion with the evolution of gas, I may remark, that their absence in roots and old stems, their rarity in petaloid parts, and their obliteration in parts which are etiolated, would seem to prove that they serve for the exhalation of oxygen: since these different organs are deprived of this function; but, on the other hand, they are absent in submerged leaves, fleshy fruits, and all cellular plants. Now, as all these organs exhale oxygen when they are green, we can only say that it may be the stomata which fulfil this office; they exist in coloured leaves, and in some petals which do not exhale oxygen.

Théodore de Saussure has made known the manner in which plants absorb oxygen during the night; and he seems to think that this absorption is performed by the stomata, because succulent and marshy plants, which have few, absorb less than others. But, 1st, Herbaceous plants, which have many, are not those which absorb most gas. 2d, This function is performed during the night, at which time the stomata appear closed. We are at present acquainted with the nocturnal absorption of air in too limited a number of plants, to be able to form an opinion upon the function of the stomata in this respect; we must be informed, in particular, if fleshy fruits, petals, and cellular plants, which are devoid of stomata, absorb air.

We can with less uncertainty appreciate the action of the stomata with regard to their perspiration of water. They exist in all the foliaceous parts, where we know that this function is performed; they are in greater abundance in plants with membranous leaves, which perspire much, than in those with fleshy ones, which perspire little; they are wanting in aquatic leaves, etiolated surfaces, fleshy fruits, petals, and roots, which do not appear to perspire, at least not in a manner analogous to leaves. They are closed during darkness, that is to say, when the perspiration ceases; and are open to the sun, that is, when they perform this function more. Finally, they are absent in cellular plants, where perspiration does not take place as in other plants. We must distinguish simple evaporation, which takes place through the tissue, in all the organs, in graduated and moderate proportion, from the perspiration, which is caused by the effect of solar light in great quantity only in the organs furnished with stomata, and which, I think, is performed by them. It is from not having made this distinction, that incorrect objections have been made against this theory; which Hedwig first indicated in 1793; which I established in 1801; and which has been since confirmed in 1802 by Sprengel, and in 1807 by Link and Rudolphi.

The contrary opinion has been maintained by Schrank, who thinks that the stomata are employed to draw moisture from the air. I believe that the absorption of aqueous vapours by the leaves is a phenomenon either rare, or contrary to the natural course of vegetation: the plants where this is most striking are the aquatic Algæ, which evidently absorb the circumambient water by their whole surface; but these plants have no stomata, and, consequently, this example would prove contrary to this opinion. Among vascular plants, those in which the absorption of water appears most evident are those of a succulent nature, which, as we know, live for a long time when separated from their root, seeming as if they were nourished by the air. I am assured by experiments, that these plants constantly lose weight when they are suspended in a sheltered place, but that if they are then plunged into water, or are exposed to rain, they regain, in a very short time, all the weight which they had lost: therefore the stomata, in their ordinary state, do not abstract moisture from the air; but withered or faded leaves absorb water which is in contact with them. Is this by the simple hygroscopicity of the tissue, or by the stomata? There are circumstances which may favour this last opinion.

Bonnet has seen that certain leaves are able to live by having water applied to one or both of their surfaces; and it seems evident, from these experiments, that they absorb the water by the surface in contact with the fluid; for, in order that the leaf may live, the face which bears the stomata must always be applied to the liquid: so that they appear to be, in this case, absorbing organs. However, when this experiment is performed with a coloured fluid, the colouring particles never penetrate the leaf; whence it will be, perhaps, more exact to conclude, that if the leaves, supplied with water upon the surface which is provided with stomata, preserve themselves fresh, this is only because the contact of the water arrests their perspiration: this is illustrated artificially in the state of a fleshy fruit, which, not having any stomata, remains fresh for several weeks, or even months.

I think, then, in conclusion—1st, that the customary use of the stomata is for perspiring water, which must be distinguished from simple evaporation;—2d, that it is not impossible that they may also serve, in some cases, for absorption; but that the experiments are all explained pretty well by the hygroscopicity of the tissue; —3d, that it is equally possible that they absorb water during the night, but that the experiments are not sufficiently multiplied to enable us to assert it.

Independently of the stomata, which are quite visible, it is probable that the surface of plants is pierced through with imperceptible pores: these might appear, after the progress of vegetation, to exist in the external walls of the cellules, or on the cuticle, but so small that the strongest microscopes cannot make them perceptible; and they are only supposed to exist from the physiological phenomena which take place. Thus, when we expose to the air a part of a plant which we know from observation to be devoid of every other kind of pore, we do not fail to remark that it gradually loses a little of its weight, and that, consequently, the fluids which it contains are found to have escaped: if we place in water a piece of the tissue of a Moss, which we know has no visible pores, it absorbs the water with an avidity which indicates the permeability of its surface. Are these pores simply inorganic, and such as philosophers admit to exist in all substances? Are they infinitely small glands, which in some cases secrete the oily, waxy, or resinous substances, which cover certain surfaces? Do they serve for the usual passage of gas and vapours, or for that of fluids? All these questions remain unanswered.

CHAPTER VII.

OF THE SPONGIOLES AND SUCKERS.

I HAVE designated under the name of SPONGY PORES *(pores spongieux)*, or SPONGIOLES *(spongiolæ)*, certain external parts of the tissue, which have a most energetic tendency to absorb the fluids with which they are in contact; and they seem, in this case, to act as very hygroscopic little sponges. They appear formed of a very close cellular tissue, composed of round cellules. At first, I only referred to this class of organs those which are observed at the extremity of the roots; but I believe that several kinds of Spongioles must now be distinguished.

1st. The RADICAL SPONGIOLES, *(spongiolæ radicales; spongioles radicales,)* are situated at all the fibrous extremities of roots. When we dissect these extremities, we only find in the interior round cellular tissue; but although the entire body of each radical fibril appears composed of an analogous cellular tissue, experience proves that it is by the extremity alone that the absorption of the sap is performed. In fact, if we place, as Senebier did, two roots in such a manner, that in the one the extremity alone touches the water, whilst the other has its whole surface plunged in, except its extremity, which is raised in the air, the former will suck up just as usual, and the other will not absorb any perceptible quantity. This experiment, which can easily be repeated with a Carrot, or *Scorsonera*, evidently proves that the extremity of roots is endowed with an entirely peculiar hygroscopic power; but if we reflect that the roots, as we shall show by and by, increase only by their extremities, we shall be strongly led to believe that that which essentially distinguishes this extremity, is, that it always presents a young membranous surface, which is not obliterated by age, and which enjoys in all its plenitude the hygroscopic property of vegetable tissue: we should consider, therefore, how the extremities of roots present phenomena so distinct, without their anatomical structure offering any thing remarkable.

Carradori, who has repeated the experiments of Senebier, obtained the same results when he employed the roots of the Radish, or the highly developed ones of other plants. He varied the experiment by placing a Radish, first, with its roots in the water and its spongioles out of it; in this case its leaves withered: afterwards the spongioles were put into the water, and the body of the root into the air, and then the leaves regained their freshness. When, on the contrary, he submitted to the same tests young plants of Corn, or the Lupine, still bearing their cotyledons, he saw that even when the roots had their extremities out of the water, they continued to vegetate: he has concluded from these facts, that the roots absorb the water by their whole surface; but from his own accounts, I conclude only that these young plants are nourished for some days at the expense of their cotyledons.

The largest Radical Spongioles which I have met with are those of the *Pandanus odoratissimus*,* of which I have given a figure. We here remark that the Spongiole is, as it were, surrounded by the remains of an epidermis, which it appears to have broken by its elongation: these remains afterwards fall off, without leaving any trace upon the body of the root, and represent a kind of broken coleorhiza. The hood which terminates the root of *Lemna* seems to be a kind of coleorhiza, which, instead of breaking at its apex for the purpose of letting the spongiole pass through, breaks at its base, and covers it as the operculum of Mosses covers their theca. We find something analogous to this in all roots which grow in water.

2d. The PISTILLARY SPONGIOLES, *(spongiolæ pistillares; spongioles pistillaires)* are the points of the female organ which absorb the fecundating liquor, in the same manner as the extremities of the roots absorb water; they are commonly placed at its extremity, and form the principal part of the stigma: when we dissect this, we only perceive a cellular tissue, which seems to offer nothing particular in its structure. We shall return to these when we speak of the Organs of Fecundation.

3d. The SEMINAL SPONGIOLES, *(spongiolæ seminales; spongioles sêminales)* which are placed upon the surface of the seed, and through which the moisture penetrates, which makes it grow. We shall see, in fact, when we treat upon Germination, that these spongioles appear, in each class of seeds, to be placed with some regularity, and that they enjoy all the properties of the other kinds of spongioles.

The Radical, Pistillary, and Seminal Spongioles, have the following remarkable properties in common:—

1st. That these organs are the places where the cellu-

* See the chapter on Roots.

lar tissue enjoys its hygroscopic property in the highest degree.

2d. That they perform a very marked degree of absorption without any peculiar visible organization.

3d. Moreover, that they absorb* the colouring particles of fluids; while these particles never pass through the stomata, which are infinitely larger than any of the pores with which the surface of the spongioles is provided.

This last circumstance is moreover very remarkable, when we consider that the colouring particles pass through the close, compact, and almost stony tissue of the surface of the hardest seeds; and do not penetrate leaves, the tissue of which is so loose, and furnished with pores, very visible under the microscope, and which most assuredly absorb, at least in certain cases, the water with which they may be in contact. This example, among many others, proves to us how even the most delicate anatomy is far from making us acquainted with the intimate nature of organized tissues.

We must, perhaps, class with the Spongioles, the extremities of the Tufts, or Root-like Hairs, which are observed in several lichens; and perhaps also the absorbing extremities of certain Suckers—as, for example, in the Dodder. These are points to be cleared up, and which I leave to the examination of anatomists. As for the analogy of radical hairs with the spongioles, we shall speak of it shortly.

SUCKERS *(haustoria; suçoirs)* are kinds of tubercles, which spring from the side of the stem of some parasitical plants, as the Dodder *(Cuscuta)*; and are destined for the purpose of absorbing nourishment from the

* Kieser asserts that the colouring particles only enter into the roots when their extremities are cut off: I know that in this case their absorption is much easier; but I have seen some roots, plunged into coloured water, absorb red particles, and become coloured internally, in cases where I could not suppose any rupture of the tissue to exist.

plants to which they adhere. These organs are found but very rarely, and I even doubt if they exist anywhere but in the Cuscutaceæ: their intimate organization has not, as yet, been studied with care; they present a tubercle, the apex of which is hollow, and it is by this cavity, which is applied to the bark of the plant which supports the *Cuscuta*, that the nourishment penetrates the sucker.

What is the internal structure of Suckers? Are these organs analogous to Spongioles? What is the mechanism by which their action is performed? We are completely ignorant upon these subjects; and I only mention them here for the purpose of calling the attention of observers to them.

CHAPTER VIII.

OF LENTICELS.

GUETTARD was the first who described, under the name of Lenticular Glands (*glandes lenticulaires*), the spots which are observed upon the rind of the branches of trees. These spots are, as Vaucher has well observed, at first oblong in a longitudinal direction, then round, and afterwards oblong transversely; they sometimes present a flat surface, remarkable because the cuticle appears there as if it were dried up; they often become convex, and frequently finish by bursting. Beneath the cuticle is found a pulverulent mass, sometimes greenish, at others whitish, which seems composed of the cellules of the cellular envelope disunited, and of the form of oval vesicles. As there is nothing which announces a glandular organization in these organs, I have given them the name of LENTICELS (*lenticellæ; lenticelles*) for the purpose of avoiding a hypothetical term—and, nevertheless, to use the primitive name, which describes their form pretty well; and to have, at the same time, the advantage of employing a simple, instead of a compound term. Du Petit-Thouars gives them the name of Cortical Pores (*pores* *corticaux)*, but these organs must not be confounded with the Stomata, which are likewise called Cortical Pores. In order to avoid this confusion, it seems to me more advantageous to employ a distinct name for each organ. The change of form of the Lenticels is the most remarkable circumstance which they present at first sight: these changes are especially visible in trees the bark of which remains a long time smooth—as the Cherry and Birch; the Lenticels are here seen in the first year oval in a longitudal direction, very small, and scarcely visible; afterwards the distension of the branch, by its increase in diameter, renders them rounder and larger; in proportion as the distension continues, they become more oblong transversely, and finish by forming kinds of horizontal, and often very distinct lines: on the contrary, when the bark of trees is cracked or split, they disappear very rapidly. In *Cineraria præcox*, which has a fleshy bark, the lenticels are very large, and preserve an orbicular form during the whole life of the plant.

These organs exist in the bark of almost all Dicotyledonous trees, except the Coniferæ, Roses, &c. They are generally absent in herbaceous Dicotyledons; Vaucher, however, has observed them in *Malva sylvestris* and *Sambucus ebulus*. No vestige of them is ever found either in Monocotyledons or Acotyledons. It is from the lenticels that the roots to which the branches give origin arise, either naturally in the air, as in *Rhus*, *Ficus*, &c. (Pl. 6.*) or when they are produced either in water or a moist soil, as in layers and cuttings. When the lenticels have been removed, and most probably when they are wanting, or are not developed, adventitious ones are formed on the branches under favourable circumstances, and these give origin to roots just as the

* This represents the roots proceeding from the lenticels of *Ficus elastica*.

ordinary ones. We may therefore say with reason, that these organs are the root-buds; they differ from the common buds, which produce branches with leaves or flowers, both in the nature of their productions, and in their form and their dispersion. They are distinguished from bulbs, because these produce at the same time roots and leaves, while the lenticels only give origin to roots. They do not absorb any thing from the exterior, as the Spongioles; and do not appear by any means destined for evaporation, as the Stomata.

Their number, size and appearance vary much in different trees, and often even in the species of the same genus; thus the *Euonymus verrucosus* obtains its name from its lenticels being very numerous and convex, whilst in the other species they are almost flat and widely dispersed.

Circumstantial details of these organs may be found in two memoirs which I have published upon the subject, in the *Annales des Sciences Naturelles* for 1826 and 1827.

CHAPTER IX.

OF GLANDS.

THE word GLAND (*glandula; glande*) signifies, in animal anatomy, a secreting organ, that is to say, an organ which elaborates a common nourishing fluid, a peculiar juice or humour. The same signification ought to be preserved in the anatomy of plants; but it must be confessed, that in these modern times, botanists, guided by false analogies, have given this name to very heterogeneous organs, several of which have not the slightest resemblance to glands. At the commencement of the science, the smallest tubercle was described under the name of Gland. It is to Guettard that we owe the most complete description of these organs; but it must also be acknowledged, that to him is due the greatest part of the errors which have been, since his time, repeated by all authors. He has also given the name of Scaly Glands (*glandulæ squamosæ; glandes écailleuses*) to the little scaly pellicles which are found upon the leaf of the Fern, which are nothing more than the coverings of their fructification.—(*Vide* Book III., Chap. VI., Sect. 1.)

The same author has applied the name Miliary Glands (*glandulæ miliares; glandes miliaires*) to the Stomata, which we have described in one of the preceding chapters.

Under the name of Globular Glands (*glandulæ globulares; glandes globulaires*) some have described certain spherical bodies, which cover the inferior surface of the leaves of some of the Chenopodiaceæ—as the wild *Orach*—and which are secreted matters analogous to glaucous powder; others have applied this name to the little spherical globules which are observed upon the leaves of the Labiatæ, the nature of which is not well known.

Vesicular Glands (*glandulæ vesiculares; glandes vésiculaires*) are vesicles full of essential oil, situated in the leaves of the Myrtle, the rind of the Orange, &c. We do not know if these are true glands, or simple reservoirs of a fluid secreted by some neighbouring organ. We shall revert to this subject when we speak of the Receptacles of Proper Juices.

Utricular Glands (*glandulæ utriculares; glandes utriculaires*) are projecting vesicles full of limpid alkaline fluid, formed upon the convexity of the external cellules; as, for example, in the Ice-plant, (*Mesembryanthemum crystallinum.*) We shall return to this article when speaking of Hairs.

Lenticular Glands (*glandulæ lenticulares; glandes lenticulaires*) are little spots which are found upon the branches of trees, and which indicate the points from whence adventitious roots may be developed under favourable circumstances. We have described them above under the name of Lenticels.

All these organs, and others resembling them, most improperly deserve the name of Glands, which we intend to reserve for the following:—

1st. Urceolate Glands (*glandulæ urceolares; glandes à Godet*) are little fleshy, often concave, tubercles, which commonly effuse viscous fluids. They are found, for example, upon the petiole of the Amygdaleæ, as the Cherry. These organs appear to be true excretory glands: those which are found at the extremities of the notches of leaves, although often different in their form, do not appear to differ from these in their nature.

2d. Nectariferous Glands (*glandulæ nectariferæ; glandes nectarifères*) are organs of very different forms, which exist in flowers, and most frequently exude a honey-like fluid: these are true glands, which we shall describe under the name of Nectaries.

3d. The Glands which are found at the base of certain hairs, as in the Nettle.

4th. Those which are situated at the summit of some hairs, as in the Chick-pea. We shall revert to these two last kinds when we treat of Hairs.

We see, from this rapid enumeration, how much negligence there has been in the study of glandular or glanduliform organs. Mirbel began to investigate them in a manner more conformable to our real intention, which is the anatomy of them; and he has already remarked, in this point of view, two kinds of Glands, distinct from each other in their structure.

1st. Cellular Glands, (*glandulæ cellulares; glandes cellulaires*), which are formed of a very fine cellular tissue, and have no communication with the vessels. Most of them distil a peculiar fluid, whence we may presume that they are *excretory*, that is to say, they are destined to carry out of the plant an excreted fluid; such is the yellow band which is found at the bottom of the calyx of *Saxifraga crassifolia;* the glands which surround the shorter stamens of the Wall-flower (*Cheiranthus Cheiri*); those which are placed at the base of the Crown Imperial, &c.

2d. Vascular Glands (*glandulæ vasculares; glandes* *vasculaires*) present, as the preceding, a cellular tissue of a coarse texture, but traversed in different directions by vessels. They do not exude a particular fluid: this causes us to think that they are recrementitial, that is to say, that they are destined to prepare a particular fluid, which is again absorbed, and employed in the interior of the body of the plant; such is, for example, the thick and whitish appendage which is found at the bottom of the flower of *Cobæa.*

This division into Cellular Excretory and Vascular Secretory Glands, deserves to be studied in a greater number of plants than it has hitherto been. But independently of glands visible to the eye, there certainly exist in plants a great number of points or glandular surfaces, which secrete certain fluids, which have as yet escaped our anatomical researches.

To complete the narrative of our actual knowledge with regard to glands, it is necessary for us to examine the Hairs, and Reservoirs of Proper Juices; this will form the subject of the following chapters.

CHAPTER X.

OF HAIRS.

Section 1.—*Of Hairs in general.*

Under the common name of Hairs (*pili, villi; poils*) are generally described all those little soft filiform productions which are observed upon the surface of plants, and which, in fact, greatly resemble the hairs of animals in their form, and, in some respects, in their structure and history.

The Hairs of plants are entirely prolongations of one or several cellules, which, by their projection, are prominent above the surface; thus, between a Vesicular Gland, for example, and a Hair, there is no other difference than the peculiar form of the two organs. We ought to distinguish several classes of hairs, which only resemble each other in their general form, but differ much in their use, their origin, and their structure: in each of these classes we may range several kinds of hairs, which have received particular names in botanical works. Guettard, who first attentively observed them, and who, from this examination, endeavoured to classify plants, has multiplied the terms relating to these organs; and although they are for the most part of little importance, we think we ought to give them rapidly, because they will afford us an opportunity of passing in review the different forms of hairs. I will arrange them under these general classes, viz.

1st. GLANDULAR HAIRS.
2d. LYMPHATIC or NON-GLANDULAR HAIRS.
3d. COROLLINE HAIRS.
4th. SCALY HAIRS.
5th. CILIÆ.
6th. RADICAL HAIRS.

SECTION II.

Of Glandular Hairs.

GLANDULAR HAIRS themselves are of two kinds—viz. the GLANDULIFEROUS *(pili glanduliferi; poils glandulifères)*, which support particular little glands; and the EXCRETORY, *(pili excretorii; poils excrétoires,)* which are the canals, or prolongations, by which the fluid contained in a gland is evacuated.

Under the name of GLANDULIFEROUS HAIRS, we may join those which have been called—1st, Cupulate Hairs, *(pili cupulati; poils à cupules*—Pl. 3, A); these are little filaments terminated by a concave gland, for example, in the Chick-pea, where this gland exudes an acid juice;—2d, Capitate Hairs, *(pili capitati; poils en tête*—Pl. 3, B); these are simple filaments terminated by a glandular spherical swelling, as in *Dictamnus albus;*—3d, Polycephalous Hairs, *(pili polycephali; poils à* *plusieurs têtes)*; these are branching filaments, each branch of which is terminated by a little glandular head, as we see, for example, in *Croton penicillatum.*

Under the general denomination of EXCRETORY HAIRS, I comprehend the excreting canals of certain glands: such are, for example, Stings, or Awl-shaped Hairs, *(pili subulati; poils en alêne)*; or those the gland of which is sessile upon the part which bears it, and is prolonged into a tubular and sharp process, as we see in the Nettle, (Pl. 3, C.) Of this kind, also, are the *Pili Malpighiacei; Poils en navette* (Pl. 3, D), the glandular base of which bears a horizontal hair, attached by its centre, and tubular in the interior: through its two extremities it gives passage to a fluid enclosed within it; this is what takes place in *Malpighia urens.*

It is worthy of remark—1st, that in all the glands provided with excretory hairs, the fluid which they secrete is of a caustic nature;—2d, that this fluid, which never flows out naturally, is only directed to the outlet which is prepared for it, when the gland, being pressed by a foreign body, allows it to escape: it then follows the course of the excretory canal, which, by its sharp extremity, deposits it under the epidermis of the animal which happens to touch it imprudently. This organization is exactly analogous to the structure of the poison-fangs of serpents.

Section III.

Of Lymphatic, or Non-glandular Hairs.

The Non-glandular, or, as they are frequently called, Lymphatic Hairs, are much more common than the preceding, and resemble them in reality only in their general form. They are filaments projecting from the surface, and formed of one or several cellules; they have, as yet, only been classed with regard to their external appearance, their consistence, their direction, or their form.

Thus, as regards their consistence, we remark, that some are very tender, others very rigid, and most are of all the intermediate degrees. With regard to their direction, some are vertical, or perpendicular, to the surface from which they spring; some more or less incline forwards; others more or less backwards; some are perfectly straight, others hooked at the point; there are several which are contracted, or which are interwoven with one another. As to their form, they are found as cylinders, and very cylindrically elongated cones. They are sometimes seen in the form of reversed cones; among those that are ramified, they are found forked, with two, three, or a greater number of branches; or starred at their apex, or divided at their base into branches, which seem as so many distinct hairs reunited into bundles, having a common base.

I have enumerated in the Glossology all the different modifications of the hairs, and the differences which they cause in the external appearance of plants; and I have pointed out the terms by which they are designated; but it is now proper to consider them with regard to Organography. The principal differences of form which deserve to be mentioned, are the following:—

1st. Simple Hairs, (Pl. 3, E,) or those formed by the elongation of a single cellule; they have, consequently, no division inside, or ramification: these are the most frequent of all in the vegetable kingdom, and are commonly cylindrico-conical, or conical, and very variable in their length, consistence, direction, and number.

2d. Divided *(cloisonnés)* Hairs, (Pl. 3, F,) or those formed of several cellules placed end to end in a single row, and separated by partitions more or less visible: they often have the name of Articulated Hairs given to them—a term evidently incorrect, since there is not in any of them any kind of articulation, or natural point of separation. They may be distinguished according as they present a cylindrical or conical appearance, which takes place when the cellules are not swollen up; or rough and strangulated, or moniliform, (Pl. 3, G,) which is due to the cellules being often swollen out between the partitions, whence results their necklace-like appearance.

3d. Branched *(rameux)* Hairs are formed of several cellules, which, instead of being placed end to end, diverge in different directions. We know that these modes of ramifications can vary much without the nature of the hair being much altered: it is here that we class the forked or Y-shaped hairs of *Alyssum;* the trifurcated or trifid ones of several Cruciferæ; the dichotomous ones of some Cruciferæ; the *Pili Malpighiacii, (poils en navette,)* or those which, divided at their base into two branches, spread upon the surface of the leaf, and directed in a single line, seem like little shuttles placed horizontally, as is seen in *Astragalus asper;* those radiating at the apex; those which ramify at the base, and appear in bundles, as in the Marsh-mallow, (pl. 3, H.); the brush-shaped *(en goupillon,)* which are knotted hairs, each knot of which produces a whorl of hairs, as in *Phlomis;* and, lastly, shield-shaped, *(en écusson,)* which are hairs radiating from a common base, and all united together in a horizontal disk attached by its centre, as in *Elæagnus*, (pl. 3, I.)

4th. Needle-shaped, *(aculeiformes.)* I describe under this name hairs which, instead of being formed of a simple series of cellules, are formed of several agglomerated, as in cellular tissue; and the union of which, projecting from the surface, has the general form of a hair. These organs are usually thicker than common Lymphatic Hairs; and several of them have a tendency to blend either with the glanduliferous, or with stings. There is not even any precise character by which they may be distinguished, unless it be their softness, compared with the stiffness of stings; but as this character admits of all intermediate degrees, it is really impossible to distinguish with precision the needle-shaped hairs from true stings.

Lymphatic Hairs only arise from the parts of plants exposed to the air; thus, they are not found either upon true roots, except at the moment of germination, or upon the portions of stems or branches buried under ground, or in any of the parts ot plants which grow under water. They are frequently found upon young stems or branches, and sometimes they remain even upon the trunk; they are common upon leaves, stipules, and the calyx, especially upon their inferior surface; they are rarely found upon the superior part when not upon the inferior. This, however, is observed upon the seminal leaves of the Nettle, and upon the common ones of *Passerina hirsuta*, &c. They are found also upon the petioles and peduncles, upon the external surface of pericarps, but very rarely on the internal; the valves, however, of the fruit of *Jacksonia* afford an example of this. The Hairs of Seeds ought rather to be placed in the class of Scaly Hairs. Some corollas bear lymphatic hairs, and others have corolline ones.

The general position of Lymphatic Hairs, then, upon parts exposed to the air, proves that the use of these organs is connected with the atmosphere.

They are in general rare in plants which grow in the shade, or in rich and moist places; and are completely absent in those which are etiolated, or have been grown in the dark: on the contrary, they are more abundant, generally, in those which grow in warm and dry places, much exposed to the sun.

From these facts it has been generally concluded, that the Lymphatic Hairs are evaporating organs; for they are found in small quantity in plants which evaporate little, and in great abundance in those which evaporate much. I confess that I am led to draw a contrary conclusion, and to believe that the hairs are natural obstacles to evaporation, because they defend the parenchymatous parts from the action of the solar light, which is the chief agent of evaporation. We know, therefore, the reason why they are wanting in plants, or parts of plants, which are placed in circumstances little favourable to evaporation; such as those which are etiolated, and also those that are succulent and aquatic, which have few or no stomata; or those growing in shady places which imperfectly receive the action of the sun. On the contrary, they are very abundant in plants exposed to the full solar action, and which would be dried up by a too powerful evaporation.

I am confirmed in this opinion by comparing the Hairs with the Stomata; these two organs, although they appear sometimes mingled, have each a fixed place: the latter exist upon the parenchyma, and assist in the evaporation; the former constantly spring from the veins or their ramifications: but the veins are the parts which least assist in the evaporation; and, consequently, it is not likely that the hairs, which invariably arise from them, serve for this purpose; we know, on the contrary, that the hairs, when they are long or abundant, cover the stomata of the parenchyma, shade them from the action of the solar light, and tend also to diminish its action when it is too intense. Thus we have the reason for a circumstance which appears singular—viz. that the hairs are almost always placed in plants upon the same surfaces which bear the stomata; thus, the upper surface of leaves, which most frequently have no stomata, have, in general, few or no hairs; whilst they are usually abundant on the inferior surface, where the evaporating organs are. It would, moreover, be extraordinary to attribute the same use to two such different organs—to Stomata and Hairs: and, lastly, the other accessory offices which the hairs perform, are all referable to the protection of vegetable surfaces from atmospherical inclemency.

In several cases, the Lymphatic Hairs serve to protect delicate organs from the coldness of the air: we remark this very evidently in the thick down which is found on young leaves when they are enclosed in the buds, or when they are just about to burst forth. Any one can satisfy himself upon this point by inspecting a bud of the Horse-chestnut: these soft, long, and curled hairs retain the air enclosed around these delicate organs, and prevent the access of the external temperature, exactly as the fur of animals; they fall off or are destroyed usually when the organs have gained more consistence, or when they have passed the critical season. We are acquainted with a multitude of examples of organs which are downy in their infancy, and which become even smooth in their adult state.

We cannot deny that hairs are, in several cases, a shelter from external moisture: thus, when we plunge into water the leaves of the Raspberry, for example, we see that the inferior surface, thickly covered with very small hairs, comes out of it without being wetted, because these small hairs retain upon the leaf a stratum of air which protects it from the immediate contact of the water. Most downy surfaces present this phenomenon in a more or less distinct degree. It is remarkable that most smooth surfaces have some other means of protection against wet—as, for example, being covered with a glaucous powder, or wax, or slimy, oily, or viscid substances not miscible with water.

Lastly, there are cases where hairs evidently serve for protection either against insects or wet; thus, for example, the calyx of the Labiatæ, which is not closed after flowering, presents in the interior little hairs lying down, or with difficulty visible, during the time of flowering, which are raised up or elongated afterwards in such a manner as to close the orifice of the tube, and defend its aperture either from insects or rain. One would be inclined to believe that the stiff bristly hairs which are found on several plants, are their defence against insects; and the analogy of certain hairs with stings tends also to confirm it.

The hairs of plants, then, are decidedly like those of animals—the protecting organs of the surfaces upon which they are developed. They protect them either against an excess of solar light, the variations of the temperature, wet, or sometimes against insects. I know that in each particular case it is not always easy to assign the function of the hairs; I believe, however, that the general theory can be but little doubted.

The diversity of form in hairs, which is sometimes met with upon the same surface, is probably connected with their different uses: thus it is possible that some serve as a defence against insects, and others against wet, or the too intense action of the light.

The difference in hardness ought probably to be also assigned to the same cause: thus there are some hairs which are destroyed or fall off early; such are those of the buds of which I have before spoken, and which are destined to protect the young shoots from cold and damp. In general, the hairs spring from the veins of stems or leaves at the time of their first development; whence it results, that, by the gradual increase in size of these organs, the hairs have a tendency to separate from one another, without their total number however being diminished: thus it is not rare to see leaves or ovaries, which in their infancy are entirely covered with very thick-set hairs, appear in their adult state only to have a small number, because the increase of the surface in all directions has caused them to separate from one another. The reverse phenomenon is also met with, though very rarely. I have already spoken of the hairs which are developed in the calyx of the Labiatæ after flowering; there is another curious example of this late development of them, which has been pointed out to me by M. Deleuze: the panicle of the Sumach *(Rhus cotinus)* is almost entirely smooth during flowering; after this period, those pedicel which bear fruit still remain smooth or scarcely pubescent, whilst those the fruit of which is abortive (and this happens in the greatest number) have a considerable quantity of hairs developed on them, so as to give them a bristly appearance, whence gardeners have given this shrub the name of the *Arbre* *à perruque:* perhaps the sap destined to nourish the fruit, not finding any office to perform when these have failed, produces this extraordinary development of hairs.

Some filaments of stamens—those of *Verbascum, Tradescantia,* &c. for instance—also become hairy when the anthers are abortive, and probably from the same cause.

In the examples which I have quoted, it seems that hairs owe their development to a great abundance of nourishment; whilst in the greater number of cases it appears that too great an abundance of nutriment tends to diminish the number; thus the plants cultivated in fertile land have less than those in sterile: in this case is all the sap carried entirely to the development of buds, or of the parenchyma, and not for the formation of hairs?

Section IV.

Of Corolline Hairs.

I designate under this name the hairs which are found upon petals, and upon perigones, stamens, and styles when they are of a petaloid nature; thus we find upon the corolla of *Menyanthes,* and upon those of the Cucurbitaceæ, and a multitude of other plants, coloured hairs evidently similar to the nature of the petals. These present almost all the forms which are found in lymphatic hairs; thus they are seen Simple, Divided, Branched and Needle-shaped; but we cannot, however, confound them with true lymphatic hairs, which sometimes exist upon the same organs: thus certain standards of the Leguminosæ, or certain corollas of the Campanulaceæ, present hairs which appear like ordinary ones, whilst the stamens of *Verbascum* and *Tradescantia* have them very different. The function and use of Corolline Hairs, are still more difficult to determine than those of the Lymphatic, and all their history is at present very obscure. I only mention them to draw the attention of observers to them.

Section V.

Of Scaly Hairs.

Under the name of Scaly Hairs I here designate a particular kind, of a dry and scaly nature, which, in different parts of living plants, are presented in a dead or atrophied state, and which hardly enjoy more than the hygroscopic property inherent in vegetable tissue: this property is so much the more perceptible, the more completely the hairs are devoid of sap. Of this kind are the hairs, expanded into scales, which are found upon the petioles of the Fern; those which compose the pappus of the Compositæ, Dipsaceæ and Valerianeæ; the tufts which grow upon the glumes of grasses, or those which surround the fruit of *Eriophorum;* the long hair which arises from the seeds of the Onagrariæ, and of several Apocineæ; the hairs which cover the seeds of the Cotton-plant (*Gossypium*), and those of *Bombax*.

All these hairs are more or less like the lymphatic in their form, but they differ in their origin, and seem to be simple strips of an atrophied membranous surface; thus, the hairs of the pappus are evidently the rudiments of their calyx, and the tufts which crown several seeds, are like the membranes which border them in analogous plants. Each of these kinds of hairs will be spoken of more in detail when we treat of the general organ of which they form part.

I mention these Scaly Hairs here only for the purpose of remarking, that although in some cases they may serve, like the Lymphatic Hairs, to protect certain delicate organs from cold, insects, wet, or the too strong action of light, they have in general an entirely peculiar function, determined by their hygroscopic faculty: thus the hairs of the pappus of Compositæ remain upright as long as they are moist, and have a tendency to fall in proportion as they become dry; in falling, they lean either upon the involucrum or upon the neighbouring flowers; and not being able to separate them, they re-act upon the fruit to which they are attached, and raise it out of the involucrum; then the least wind which happens to blow on the kind of network formed by the radiating hairs of the pappus, lifts it up and carries it away with the fruits.

These hairs, then, are found to serve eminently for the dispersion of the monospermous fruits of the Compositæ: it is also remarked that where they are absent, there always exists some other circumstance in the organization which supplies their place; sometimes, as in *Anthemis*, the receptacle rises in the centre, and pushes the fruit out; sometimes, as in *Chrysanthemum*, the scales of the involucrum fall when mature; at others, as in *Carpesium*, the head of flowers leans over when the fruits are ripe, in such a manner that they fall out by their own weight, &c.

The Dipsaceæ, furnished with a pappus, and the Gramineæ and Cyperaceæ, provided with beards, &c. present similar phenomena. The plumes which crown a great number of seeds enjoy properties of the same kind, and serve by their separation to make the seeds fall out of the pericarp, and favour their dispersion by the air; of this kind are those of *Epilobium*, the Apocineæ, &c.

These examples, which could be easily multiplied, tend to prove that Scaly Hairs enjoy very decided hygroscopic properties, by which means they perform certain offices necessary for the dispersion of seeds.

Section VI.

Of Ciliæ, Bristles, &c.

Under the name of Ciliæ, are described the hairs which spring, not from any surface, but from the border of that surface, in such a manner that they do not arise either from the superior or inferior face of a membrane, but are on the same level with them. They put on all the appearances of Hairs; thus some are Glandular, some Lymphatic, others Corolline. In general, their presence is more regular and constant in the species which are furnished with them, than that of Hairs properly so called. Most are of a little stiffer nature than hairs, and several are confounded by their texture with stings, spines, or even with the indentations of leaves. Their use appears to be only to protect the leaf from the attacks of insects; but even this use is not presented in a sufficiently evident manner.

When the leaves or their lobes only bear a hair-like appendage, this receives the name of Bristle *(seta; soie)* when it is truly a hair, as in *Papaver setigerum*, or *Chenopodium setigerum*, which receive their name from it. When the appendage is short, or a little thick, or has somewhat the appearance of a sting or spine, the name of Mucro *(mucrone)* is applied to it: we see this particularly in all the Menispermeæ, and a multitude of other plants.

Section VII.

Of Radical Hairs.

All the kinds of hairs of which we have spoken grow upon the stems, leaves, and in general upon all the organs of plants which are above the neck, and which form part of the ascending vegetation; but the roots also have a kind of hairs; these are very small, extraordinarily fugacious filaments, which are produced especially during the first infancy of the plant, upon those roots which are exposed to the air. Carradori, who has well observed these organs, has remarked that they never arise from roots sunk in water, nor on the parts of them which this liquid surrounds; that they are developed especially upon roots exposed to a moist air, and that darkness is very favourable to their growth. These filaments resemble true Hairs in their form and anatomical structure, but their use may be very different, and resemble that of the Spongioles. Carradori considers them as organs destined to absorb the moisture of the air, as the spongioles absorb water; and the opinion appears very likely. Ought these hairs to be confounded with the fibrilles ? * I am still in doubt; and it must be confessed, at least, that if the fibrilles of roots are kinds of hairs, as Kieser says, they differ from those which I here designate, in their longer duration, their firmer texture, and perhaps in the faculty of one day becoming branches of the root; whilst the Radical Hairs are very fugitive and soft, and never appear to be transformed into branches. This subject, which has scarcely been studied, merits the examination of observers. I will add, also, that the hairs which are found at the base of several fleshy Fungi are very nearly allied to the Radical Hairs of vascular plants.

CHAPTER XI.

OF THE RECEPTACLES OF PROPER JUICES.

UNDER the name of PROPER JUICES *(sucs propres)* have been for a long time described those coloured fluids of a peculiar nature which are found in certain plants; and the vessels in which they are stored up have been called PROPER VESSELS *(vaisseaux propres)*. They were so compared to true vessels, that it is only within these few years past that they have been studied with any care. We will speak of the Juices when we treat of the Secretions of Plants: we are now only about to describe the form of the vessels which contain them.

* French Chevelu.

It appears from the admirable observations of Bernhardi, Mirbel, and Treviranus, upon this subject, that the Proper Juices have no perceptible motion, and that they only come out of the plant when the envelopes which shut them up are broken. These envelopes are, in general, thicker and firmer than those of Lymphatic Vessels; they are always devoid of every kind of dots or rings, so that they are easily known by this character when they are beheld under the microscope. They are better distinguished by their generally being of a larger diameter than true vessels, and especially in not having such regular forms, and from the walls which enclose them not appearing to belong to them: it seems, as Grew has indicated, that the Proper Juices, secreted in certain parts by glands or membranes as yet unknown, are deposited in the neighbouring cellular tissue, distending or breaking it; and there form round or elongated cavities, which have a vascular appearance, but which, as is seen, differ entirely from vessels: by this hypothesis, they would be true cystous sacs, very analogous, for instance, to those which form encysted aneurisms in animals.

Link has given them the name of RECEPTACLES OF PROPER JUICE *(receptacula succi proprii)*, which exactly suits them, and which ought to be adopted in order to separate these organs from true vessels.

In considering the different forms which the Receptacles of Proper Juices present, we may arrange them in several classes:—

1st. VESICULAR RECEPTACLES *(réservoirs vésiculaires)*, which are those which authors have called Vesicular Glands; that is to say, those nearly spherical vesicles situated in the tissue of leaves,—as we see in the Myrtle, or the rind of the Orange, &c. These vesicles are sometimes slightly elongated, either when they are found in parts where the cellular tissue is elongated, or perhaps when two of the round cavities are united. These oblong vesicular glands are very frequently found in the leaves of the Samydeæ: whatever be their form, their juice never flows out unless the envelope is broken. This effusion of the juice is very visible in the leaves of *Schinus molle :* when cut into fragments and placed into water, their juice escapes in intermittent jets, which strike the water and cause the leaf to recoil. The vesicular receptacles contain volatile and aromatic oily juices.

2d. Closed Receptacles *(réservoirs en cæcum)* are kinds of short tubes, perfectly closed at one of their extremities; such are, for example, the little channels full of volatile oil, which are observed upon the fruit of Umbelliferæ, and which, commencing at the summit, extend, in different species, to a third, half, or three quarters of the length of the fruit.

3d. Tubular Receptacles *(réservoirs tubuleux)*, described by Mirbel under the name of Solitary Proper Vessels *(vaisseaux propres solitaires)*. These are tubes of indefinite length, solitary in the midst of a mass of cellular tissue. Grew has observed them very well; he has figured those of the Pine under the name of *Turpentine Vessels*, and those of the Sumach under that of *Milk Vessels.* Their walls are usually formed of a very close and compact cellular tissue, as Mirbel has seen in the tortuous reservoirs of *Pinus strobus.* The interior of these is sometimes itself filled, at their first development, with a cellular tissue, which is afterwards destroyed.

4th. Fasciculated Receptacles, or Fasciculated Proper Vessels *(réservoirs fasciculaires, ou vaisseaux propres fasciculaires)*, discovered by Mirbel. These are bundles of little parallel tubes, or very elongated cellules, which contain a proper juice: it is in organs of this kind that the proper juices of the Apocineæ are stored up; the fibres of the bark of the Hemp are only bundles of fasciculated reservoirs.

5th. Accidental Receptacles *(réservoirs accidentels)*. I have united under this name the cavities which are found full of proper juice without any regularity, and which become receptacles of proper juice without their having been originally destined for this purpose: it is thus that the proper juices often filter into the lymphatic vessels of the Coniferæ, into the cellulles of the pith of certain Euphorbiaceæ, &c.

The details into which I have entered, prove what I have before advanced—that the proper juices have not in reality an organ specially destined to contain them; they are lodged in the cavities contiguous to them, which are formed into kinds of sacs of a membranous or fibrous appearance. Those who admit the existence of intercellular passages, regard the receptacles of proper juices as formed by the distension of these canals, and the compression of the neighbouring cellules: those who deny their existence are obliged to admit the rupture and disorganization of the tissue, in order to produce the formation of the cavity destined to contain these juices. The first opinion is more easy to comprehend in its anatomical relation; but, entirely giving it the preference, I do not deny that it can scarcely be understood in this theory, why, in a great number of cases, the Receptacles are terminated so cleanly.

The Receptacles of Proper Juices, like the juices themselves, are found in several families of Dicotyledons, as the Guttiferæ, Hypericineæ, Chicoraceæ, Euphorbiaceæ, Myrtaceæ, Apocineæ, Artocarpeæ, Coniferæ, &c. They have not as yet been observed with certainty either in Monocotyledons or Acotyledons.

The different Receptacles are generally placed in the cellular tissue of the bark, and consequently are continually thrown towards the surface by the distension produced by the growth of the wood; whence it results, that they are often wanting in very old bark: these are the cortical receptacles which Hill has described under the name of *Vaisseaux Propres Extérieurs;* but under the denomination of *Vaisseaux Propres Intérieurs et Intimes* he describes indifferently very dissimilar organs, where the proper juice is sometimes lodged, and situated in the wood and pith. The true Proper Juices appear to be entirely secreted in the green, and consequently external, part of plants.

CHAPTER XII.

OF THE AIR CAVITIES.

We have seen that the cellular tissue is sometimes distended so as to form cavities where the Proper Juices are lodged; and this distension, caused by a known and visible agent, offers no difficulty; but it also often happens, as a necessary consequence of the increase in size and of growth, that the cellular tissue is distended or broken so as to form spaces, or rather cavities, full of air. Grew first observed this phenomenon, and its analogy with the formation of the Receptacles of Proper

Juice. Mirbel, who has called the attention of anatomists to these cavities, and has described them with care, has designated them by the general name of *Lacunæ*. Rudolphi, who considers them as special organs, calls them, for this reason, *Vaisseaux Pneumatiques*. Link designates very well their origin and uses, in giving them the name of *Accidental Receptacles of Air*. Kieser gives them the name of *Cellules d'Air*. A long time since I adopted the name of AIR CAVITIES *(cavitates aereæ; cavités aëriennes)*, which appears to me more exact and suitable than those hitherto proposed.

If we examine, at its first development, the interior of the stem of a grass, for instance, we remark that it is full of a dilated but regular cellular tissue, continuous throughout all its parts: after a certain time, and when the stem increases transversely, this cellular tissue, not being able to be distended beyond a certain limit, is broken, and forms in the interval between each knot a central tubular cavity, full of air, which appears lined with a dry membrane, which is nothing but a false membrane formed by the remains of the cellular tissue.

When we examine in the same manner the pith of the Walnut, we see that in its infancy it presents a regular cellular tissue full of watery juice; after a little while this juice is absorbed by the development of the branch, the pith becomes dry, the branch elongates, and the dried pith is thus broken into little transverse disks, which leave between them disciform air cavities. The pith of the White Jessamine *(Jasminum officinale)* presents in the same manner very regular disks.

The same phenomenon takes place very frequently, but with less regularity, in aquatic plants, the tissue of which is loose, and the growth very rapid; we observe in their stems, petioles, and peduncles, air cavities often very numerous, and the form of which is nearly constant in each species; because, although it be an accident, it is one caused by the structure and growth of the species. In certain species these cavities are, as we have seen, large enough to be visible to the naked eye; at other times they are so small, that they can only be perceived with a lens or even a microscope; in this last case, the spaces which result from these fissures in the cellular tissue, or from these dilations of the intercellular passages, bear a great resemblance to vessels, from which they only differ in their being less regular. Some naturalists even think that all the vessels are true accidental cavities produced by the growth of the plant; and they support this opinion either upon the analogy of the large air cavities, or upon the fact that vessels are not visible in very young embryos. But in this bold hypothesis, there would be much difficulty in explaining the extreme regularity in the form of vessels—the peculiar situation of the tracheæ, which, as I have shown, differ much from other vessels—the constant direction which the sap takes at the first moment of growth, &c. Lastly, whatever opinion one adopts in this respect, it must always be admitted that the vessels are formed long before, and with much greater regularity than the air cavities.

These cavities contain air, but we cannot assert that it performs any direct function in the act of vegetation; we must not liken them completely to certain air cavities which are formed in some organs by a true dilatation of the tissue, as we see in the floating bladders of some species of *Fucus*, of *Trapa natans*, *Utricularia*, *&c.* We shall again have occasion to revert to these organs hereafter.

CHAPTER XIII.

OF THE RAPHIDES.

I DESIGNATE by this name, which signifies Needles, very singular bodies which have been discovered within a few years, and the function of which is still very obscure: these are bundles of hairs or points, of a moderately stiff consistence, which are found either in the internal cavities, or in the intercellular passages of some plants with loose tissue. Sprengel has found them in the cellular tissue of *Piper magnoliæfolium*. Rudolphi also points out their existence in *Tradescantia* and *Musa*. Kieser has seen them in *Calla Æthiopica, Musa sapientum,* and *Aloe verrucosa*. I myself have seen them in *Tritoma Uvaria, Littæa geminiflora,* and *Crinum latifolium,* and my son has observed them in *Nyctago Jalappæ,* and the common Balsam *(Balsamina hortensis)*. I am not aware that they have as yet been found in other plants; but as these belong to two great classes of Vasculares, and to several widely-separated families, it is probable that they will be found in many others: we remark that they are only found in plants of loose tissue. We are as yet too little acquainted with them to describe them otherwise than from examples.

When a leaf of *Tritoma Uvaria* (Pl. 3, fig. 5,) is cut lengthways, we observe longitudinal fibres, in which the tracheæ and annular vessels are very easily distinguished from one another by the inequality of their diameter. Between these fibres are found a green parenchyma, composed of irregular oblong cellules, placed end to end, and evidently separate from one another. They unite towards the external parts of the veins, which are composed of elongated and close cellules. The transverse cellules, which, perhaps, are organs distinct from those which compose the fibres, contain a green rough matter. Among these transverse cellules we see kinds of opaque spindles, placed in a longitudinal direction, and parallel with the veins, pointed at the two extremities, and which seem kinds of internal hairs. These are the filaments which I call RAPHIDES; the bundles of them often diverge under the eye of the observer, and then the filaments of which they are composed can be distinctly seen. It happens very frequently that in cutting the leaf, the Raphides separate and float in the water in which it is placed under the microscope. When they are thus seen isolated, (Pl. 3, fig. 6,) they seem, under very powerful microscopes, to be kinds of tubes pointed at the two extremities; they present two opaque lines upon the borders, and the middle is transparent, as in common hairs placed under the microscope. These Raphides are of a stiff consistence; we have never seen them bent or curved—neither I, nor my son, nor the observers who were kind enough to assist us in this examination; among them it will be sufficient to mention Dr. Provost, to prove how accustomed they are to microscopic researches. It has been impossible for us to form any idea of the point of attachment, or of the origin of these bundles, which seem to be produced upon the cellules. The bundles of Raphides in *Littæa* and *Crinum latifolium* differ so little from those of *Tritoma*, either in form or position, that it is not necessary to describe them. As for *Nyctago Jalappæ*, the bundles of Raphides are presented to view immediately under the cuticle of the leaf, where it is raised by the point of a knife; they are distinguished by the naked eye or lens, as little white oblong spots pointed at the two ends. When the tissue is placed uuder the microscope, the bundles of Raphides are seen as layers under the cuticle; they are smaller than those of *Tritoma*, but they are detached in the same manner, and present the same appearance; they are also found in the articulations of the stem. Those of the common garden Balsam (*Balsamina hortensis*) differ very little from the preceding, and are also found under the cuticle of the leaves and in the articulations of the stem.

The bodies observed by Sprengel in *Piper magnoliæfolium* appear, from the figure which he has published, perfectly to resemble those which I have described; but he gives so few details of them that I cannot form a decided opinion upon their identity.

All the observers who have spoken of these bodies, have considered them as kinds of little crystals, which are formed in the juices of the plants, and are fixed in the intercellular passages. Sprengel and Kieser, in consequence, give them the names of very fine Needles (*aiguilles très-fines*) or Needle-shaped Crystals (*cristaux en forme d'aiguille*), but these terms appear to have the double inconvenience of being compound words, and of affirming upon their nature, perhaps, beyond what has been strictly demonstrated. I have decided for this reason to name them RAPHIDES (a Greek word which signifies needles); this name has the advantage of connecting their form and original name, and it does not affirm any thing beyond what is true.

CHAPTER XIV.

OF SOME PROJECTING BODIES IN THE INTERIOR CAVITIES OF PLANTS.

I HERE make allusion to two classes of very peculiar bodies which are found in the cavities of certain plants with loose tissue, and the history of which is little known; they differ from Raphides both in their form, and because they make an integrant part of the tissue, and are never found floating in the fluids.

The first kind is composed of star-shaped bodies, discovered by Rudolphi, and since well observed by Amici, in the air cavities in the stems and petioles of the Nymphæaceæ; they are kinds of stars, with several diverging rays inserted upon the border of the cavity, and projecting into the interior. The form of each ray is conical; wider at the base, and stiff. Rudolphi asserts that he has found them in the stalks, petioles, leaves, and even corolla of the Water Lily *(Nymphæa)*. Those of *Nymphæa alba* have the rays less numerous and longer than those of *Nuphar luteum;* they have even been found in the dried plants. The use of these radiating bodies is entirely unknown, but there can be no doubt that they form an integrant part of the tissue. Rudolphi compares them with the hairs which are found in the interior of the pods of some Leguminosæ and the bladders of sea-weed; but their rigidity and regularity leave me much in doubt with regard to the accuracy of this analogy.

The second kinds of bodies, situated in the cavities, and which appear to make an integrant part of the tissue, are composed of little round-stalked buttons, which Kieser has discovered in the air cavities of *Calla Æthiopica*, and which spring from their walls. The function of these organs is wholly unknown.

The peculiarity of these two classes of organs to the plants we have mentioned would make us think that their use is of little importance.

CHAPTER XV.

OF ARTICULATIONS AND DEHISCENCES.

In the animal kingdom the articulations are complete solutions of continuity between the solid parts which form the frame-work destined to support the organs of locomotion; in plants, where there is no apparatus for motion, that is to say, no muscles or bones, there cannot, consequently, be articulations analogous to those of animals.

Those parts in plants are called Articulations, where, at a certain period of life, solution of continuity naturally takes place. It is to be remarked, that all the parts of plants which naturally fall off are provided with articulations, and that all those which are devoid of them die after a certain time, and dry up and are destroyed piece-meal, but are never detached in one whole piece; this difference will very often be shown in the description and history of the compound organs. I only mention the articulations here for the purpose of considering their anatomical structure. When we examine minutely the articulations in their young and fresh state, we only remark the cellules and vessels continuous and regular; but, nevertheless, we almost always observe a little swelling or small knot, which indicates the point of the articulation; after a certain time this swelling augments, and a row of cellules, disposed upon the same plane, either dry up and are obliterated, or separate from the neighbouring row: then the fibres alone form the communication between the two parts; but as they are no longer bound together by the surrounding cellular tissue, they are broken by the slightest shake. The part exposed by the fall of the organ, which was attached by means of an articulation, is called a CICATRICE: we here distinctly perceive the places where the fibres were broken, but the cellular tissue proves, by its smooth surface, that its separation has taken place without true rupture.

The organs attached by such an articulation are said to be ARTICULATED; the others are called ADHERENT or CONTINUOUS; the former are caducous, the latter persistent. There are organs, which, as we shall see, are themselves composed of parts articulated with one another; these are called ARTICULI, when they are considered in a general manner; they receive, in different cases, particular names, which we will notice hereafter.

The Cicatrice is always more visible upon the larger of the two surfaces which are disarticulated, and it is usually to this alone that this name is applied; sometimes, consequently, the Cicatrice is marked upon the permanent organ; such is that which the leaf leaves after its fall,—those which the annual stems leave upon certain root-stocks, as in Solomon's Seal,—or those which the peduncles or flowers leave upon the stem or receptacle. Sometimes they are found upon the organ which is detached; such are the Cicatrices which are observed on the base of certain pericarps, as in the Acorn,—or those on seeds, as in the Horse-chestnut.

Dehiscence is a phenomenon which takes place in organs which are closed, at least in their infancy; it is nearly related to that which we call articulation in elongated organs: it consists of a determined and regular rupture, which is performed by a closed organ; thus, most dry fruits open when ripe, either longitudinally or transversely, by one or several regular divisions. The lines through which these ruptures take place, are most frequently a little prominent, so that they can be perceived before the dehiscence occurs: to these the name of SUTURES has been given, because they have been compared to the projecting lines on pieces of cloth which have been sewed together. But this term does not indicate that the parts susceptible of separating by dehiscence were always originally distinct; in reference to this there are two kinds of dehiscence.

1st. It sometimes takes place between organs originally distinct, which have united during their growth, and separate when ripe: this is what happens when the carpels of a fruit separate from one another at their points of junction,—as is seen, for example, in the Rhodoraceæ or Colchicaceæ; when petals, which were more or less completely joined together during flowering, separate when they begin to wither, as in some species of *Correa*. I give to this mode the name of Dehiscence by Separation *(par décollement)*. The septicidal dehiscence of fruits belongs to this class.

2d. Sometimes parts originally distinct are united together in such a manner that they cannot separate when ripe, and then the dehiscence takes place by a regular rupture, which is effected in the line which offers the least resistance: I give to this phenomenon the name of Dehiscence by Rupture *(par rupture)*. The dehiscences of fruits, termed Loculicidal, Transverse, Basal, &c. are particular cases of this class. I shall revert to the detail of the different kinds of Dehiscence when I speak of Fruits; but I considered it right to mention them here in a general manner, since all these distinctions are applicable to all hollow and closed organs in their young state; and we see from what precedes, that dehiscence is a kind of articulation applied to hollow organs, and that articulation is the dehiscence of elongated ones.

CHAPTER XVI.

DIVISION OF PLANTS BY MEANS OF THE ELEMENTARY ORGANS.

We have described in a concise and general manner, not only the elementary organs, but also those, the primary combinations of which are so intimate, that they may be considered as being themselves elementary. It now remains for us to show, in order to conclude this first part of the Organography, how the vegetable kingdom may be divided by means of the elementary organs, and how we shall obtain by it a fundamental division by which we shall see hereafter that all the secondary ones are linked together.

In this point of view, plants are divided into two great classes, viz., Cellulares *(cellulaires)*, and Vasculares *(vasculaires)*: the first are composed solely of round or elongated cellular tissue, the second both of cellular tissue and vessels. The former are constantly devoid of stomata; the latter are generally furnished with them,—with the exception of some species isolated into different groups, where these organs are absent. The former most frequently present an almost homogeneous mass, with the organs of nutrition and reproduction but little defined; in the latter, all these organs are very distinct and well characterised: the former have only a weak and uncertain tendency to rise perpendicularly; in the latter this tendency is energetic and continued. All the principal phenomena of structure and growth differ in these two classes.

Cellular Plants *(vegetabilia cellulosa)* have been named *Acotyledons* by Jussieu; *Agamia* by Lamarck; *Inembryones* by Richard; they form part of the class of *Cryptogamia* of Linnæus; and of *Ætheogamia* of Beauvais;—all these terms rest more or less upon hypotheses or partial characters. I give them the name of CELLULARES when I consider them with regard to their nutritive organs; and I employ the more extensive term of CRYPTOGAMIA, in order to comprehend the cellular plants, and those among the vascular the fructification of which is indistinct,—as the Ferns.

Vascular plants *(vegetabilia vascularia)* are often designated by the names of *Phanerogamia*, *Phænogamia*, or *Embryones*, in contradistinction to those of Cryptogamia or Inembryones; but these terms are as inaccurate as those to which they correspond. I use the name of VASCULARES to designate all the plants provided with tracheæ and stomata, whatever may be their fructification; and the more restricted term of PHANEROGAMIA *(phanerogames)* for those vascular plants the fructification of which is distinct, and more or less symmetrical.

Link prefers the terms of *Homonemeæ* and *Heteronemeæ*, to designate the classes of which I have been speaking; but I persist in preserving those of CELLULARES and VASCULARES—1st, Because they are older; 2d, Because the terms proposed by Link, which signify similar and dissimilar filaments, seem to me likely to originate inaccurate ideas.

Among Vascular Plants we can also establish two great fundamental divisions, viz :—

1st. Those which have all their vessels and elongated cellules directed longitudinally, and where the new fibres are always developed toward the centre of the trunk.

2d. Those which have the vessels or bundles of elongated cellules directed either longitudinally or transversely, and the new fibres of which are developed toward the circumference of the trunk. The former have received the name of MONOCOTYLEDONS or ENDORHIZEÆ; and the latter, in contradistinction, those of DICOTYLEDONS or EXORHIZEÆ.

I shall designate them here, sometimes by the names of DICOTYLEDONS or MONOCOTYLEDONS, when I compare them with reference to their fructification; at others by those of EXOGENS or ENDOGENS, when they are considered with regard to their nutrition.

It results from this rapid and very elementary summary, that the great primary classes of plants are the following:—

1st. DICOTYLEDONS or EXOGENS (all *Phanerogamia*).

2d. MONOCOTYLEDONS or ENDOGENS *(Phanerogamia)*.

3d. MONOCOTYLEDONS or ENDOGENS *(Cryptogamia)*.

4th. CELLULARES (all *Cryptogamia*).

The name of VASCULARES comprehends the three first of these divisions; that of CELLULARES, only the last.

The term of Phanerogamia includes the two first; that of Cryptogamia, the two last.

Those who are fond of numerical relations will remark, perhaps, that the vegetable as well as the animal kingdom presents four great primary classes; but I beg them to exempt me from attaching, for the present, any importance to this. I own, with M. Fries, that the quaternary division is frequently presented in the plans of our classification; but I do not know but that this arises rather from our turn of mind, which is fond of comparing things with each other, than from the real nature of things.

CHAPTER XVII.

OF THE GENERAL CLASSIFICATION OF COMPOUND ORGANS.

We have analyzed the elementary organs of plants, and those which are formed in a manner so immediate that they may be taken for elementary ones. It must now be examined how these different organs are combined in order to form all the various parts of plants.

In considering this subject in a very general manner, we may know that all vascular plants seem composed of three principal parts only—the stem, the root, and the leaves; and this theory may be demonstrated—1st, in this, that these three parts alone suffice for the life of the plants, and even for a kind of multiplication of these beings;—2dly, in this, that all the other known organs of plants may be considered as modifications of one of the three which have been just mentioned. It is expedient then to study directly the structure and history of these three organs; which we shall call the FUNDAMENTAL ones, to indicate both that they serve eminently for the nutrition of plants, and that all the others (as will appear in their description), are simple modifications.

Those other organs, less essential to life, but which concur, however, in a powerful manner to its support, may be classed in two divisions; the one kind, (and these are by far the more complicated and various,) are connected with the means of reproduction of plants: these are the REPRODUCTIVE ORGANS *(organes reproducteurs)*, such as flowers, fruits, &c.

The others are modifications of the fundamental organs, and are connected with other functions than reproduction, such as the support, defence, and protection of the organs in general, or of one of them in particular. I have called them collectively by the name of ACCESSORY ORGANS *(organes accessories)*.

These divisions are applicable when they relate to Vascular plants, but we must not strictly follow them in the description of the Cellular, where all the parts are more or less confounded in a homogeneous tissue. We shall take care, in the following books, attentively to separate these two great divisions of the vegetable kingdom.

BOOK II.

OF THE FUNDAMENTAL ORGANS, OR THE ORGANIC PARTS ESSENTIAL TO NUTRITION.

THE organs which I call Fundamental are those which serve for the nourishment of the individual plant, and which cannot, consequently, be wanting in any of them, though, by some particular combinations, they may sometimes be very small, or difficult to be recognised. These organs are, in vascular plants, the Stem, Root, and Leaves; and in cellular plants we shall see that they seem more or less confounded in a single body. We shall commence by studying them in the Vasculares, where they are generally very distinct, so that we may endeavour afterwards to form an idea of the Cellulares, where these distinctions are scarcely or not at all admissible.

CHAPTER I.

OF THE STEM OF VASCULAR PLANTS.

Section I.

Of the Stem in General.

Art. 1.—Of the Stem, properly so called.

The Stem *(caulis; tige)* is that fundamental part of plants which has always a tendency to rise vertically with more or less energy, and which has the root at its base, and the leaves above, when the plant is destined to have any; or, as Desvauz says, the stem is the intermediate organ between the roots and the leaves. This organ, which is that from which all the others spring in different directions, is not absent in any vascular plant: sometimes it exists very evidently and highly developed; at others it is stunted and concealed under ground, in such a manner as to appear as if there were none,—as Hedwig has affirmed since 1793, as I have established since 1804, and as Dutrochet has since confirmed by some beautiful observations. The plants in which it is very visible have been called in Latin *caulescentes*, a word which some authors have preserved in French. Those in which it is scarcely apparent have been named, in contradistinction, *acaules* or *subacaules.*

This distinction, which is convenient in descriptive language, is by no means accurate, for the stem always exists; but it is sometimes very long, at others very short, most frequently very apparent, but sometimes buried in the earth: we are about to show this by some examples.

Most plants said to be stemless *(acaules)* only owe this appearance to the shortness of that organ: their leaves and flowers appear to spring from the root, and are called Radical *(radicales)* because their bases entirely conceal the stem which gives origin to them. Nearly all these plants are capable of presenting a stem well developed when placed in favourable circumstances;—thus, *Carlina acaulis, Astragalus Monspessulanus, Carduus acaulis,* &c. &c. are as often found with a visible and developed stem as without any apparent one.

The globular and depressed body, which it has been the custom to designate by the name of a tuberous root, in the *Cyclamen,* is a true stem or stock, which gives origin to roots at its inferior side, and produces each year, at its summit, a bud with leaves and flowers. This assertion is confirmed by the mode of germination of this plant, and by the slight greenness this round body acquires when it is exposed to the light.

In bulbous plants, such as the Hyacinth or Tulip, the stem appears wholly wanting; but here analogy guides us, and clearly proves that the stem is the orbicular plate which forms the base, and which bears on one side the roots, and on the other the leaves and flowers. In fact, no one refuses the name of stem to that of the the Palms, *Yucca, Aloë,* and Lilies; but, by insensible gradations, we can descend even to that of the Hyacinth. In the genus *Allium,* for example, are found some species with an upright and very evident stem, as

Allium tataricum; there are others, where it is short, lying upon the surface of the ground, as *Allium senescens;*—lastly, in others it is reduced to a simple orbicular disk, as in *Allium cepa.*

The short and stunted stems are often difficult to be recognised, because they are found concealed under ground, as we see it in the Garlic: the same phenomenon is presented among Ferns, some of which have the stem strong and upright, like a tree,—for example, *Dicksonia:* others have it twisted, weak, and climbing, as *Ugena;* lastly, there are others (and it is these alone which grow in our climate,) with the stem creeping along the surface of the ground, or even beneath it.

This kind of subterranean stunted stem, having the appearance of a root, has been called *Rhizoma* by Ker, a name which signifies *like a root:* and it expresses its nature very well. The stems of *Nymphæa*, the European Ferns, the European species of *Arum*, and several kinds of Garlic, have Rhizomata. Hedwig gave the name of *Truncus superficialis* to stems lying horizontally upon the surface of the ground,—as, for example, the *Iris germanica.*

The *Salix herbacea* sometimes presents this subterranean position of the stem in a peculiar manner. This little plant grows in the turf upon the Alps, the soil of which is liable to be elevated by more rolling down from above: the stem, which is very short, becomes covered with earth each autumn, and in the spring it lengthens to the surface of the soil; so that, after some years, the whole stem is buried in the earth, and only shows upon the surface the herbaceous tops of its branches. When it grows, or is cultivated, in a soil which does not become elevated, the woody stem creeps along the surface; and in this case, one cannot see the reason why it is called the Herbaceous Willow.

It is, then, quite certain that the stem exists in all Vascular Plants—sometimes being large, at others small—most frequently elevated into the air, but sometimes subterranean.

The general tendency of vascular stems is to rise perpendicularly from the ground in which they grow; and this fundamental property, which we will hereafter analyse, is only wanting in a very small number of vascular plants—viz. Parasites, that is to say, those which live upon the sap prepared by other plants—as, for example, the Mistletoe and Dodder *(Cuscuta)*. In several cases this truth is scarcely evident—as, for example, when the stem or its branches are so feeble that they cannot maintain themselves erect, or when the stem is attached to the soil throughout its whole length by roots or cramps; in these cases the extremities alone show the tendency to assume the vertical direction.

The ramifications of the stem have received the names of BRANCHES *(rami; rameaux)*. The undivided part of the stem bears, in contradistinction, the name of TRUNK *(truncus; tronc)*; and the collection of branches, that of CYME *(cyma; cime)*. These branches, which are only kinds of stems, have a tendency, like the trunk, to assume the vertical direction, especially in their young state. We shall see hereafter that we ought to consider each branch as a perfect whole, inserted into the trunk or branch which gives origin to it.

The stem always bears the leaves, when it is destined to have any. There are no true stems without leaves, except those of plants where these organs do not exist, such as *Orobanche*, *Lathrea*; and yet, in these cases, the leaves are represented by scales, as in *Lathrea*, and also *Cuscuta*; or by tubercles, as in *Stapelia*.

Scapes *(scapi)* are those organs, devoid of true leaves, or only producing floral ones, which bear the flowers of certain plants, such as the Hyacinth; these are not true stems, but kinds of peduncles which spring from a short subterranean stock.—(See Book III. Chap. I. Sect. II.)

The point where the stem joins the root, and which is generally on a level with the surface of the ground, bears the name of the Neck *(collum; collet)*. Grew gave it the name of *Coarcture*. Turpin has been induced, from comparison with the animal kingdom, to call it the *Median Horizontal Line*. Lamarck designates it by that of the *Vital Node*, because it is, in fact, a kind of centre, above and below which the fibres enjoy very different properties; but these fibres appear continuous, and anatomy does not give any reason for the difference which exists among them, so that the Neck is sometimes the point of demarcation of two organs, and not itself an organ; its situation even is not always easy to be recognised with certainty. There are, in fact, certain stems, such as those of *Eryngium*, which have at the base the appearance and texture of true roots, so that they can only be distinguished by their ascending direction.

Certain stems present an interval between the Nodes *(nodi; nœuds)*; that is to say, those firmer and denser parts which appear formed either by the interlacement of the fibres, as is seen in some grasses, or more rarely by stony concretions analogous to calculi—as, for example, in the Cane, which is improperly said to be jointed. The part of the stem which is found between two Nodes bears the name of Internode *(internodium; entre-nœud)*. The leaves arise usually from the nodes of knotted stems; hence it happens that in those stems which have no nodes, the part between two pairs or two rows of leaves frequently goes under the name of

Internode: and Turpin calls the part from which a leaf or pair of them spring, the *Vital Node (nœud vital)*, thus extending by theoretical views the primitive meaning of the word.

Knotted Stems are frequently confounded with jointed ones, *i. e.* those provided with kinds of articulations, or places which can be broken without tearing the tissue. This error arises from this:—1st, that the articulations of stems are almost always provided with rims or swellings which resemble nodes;—2d, that the articulations can only be broken during the first or second year, and that afterwards they present sufficient density to seem like true nodes. However, we know without difficulty that the nodes and articulations are very distinct: the former, formed by the plexus of vessels, present points more compact than the rest of the tissue; the latter, on the contrary, are the parts of the stem which are less firm and more easily broken, thus Vitacæ, Caryophylleæ, and Geraniaceæ are articulated in their young state; the interval between the two articulations bears indifferently the names of ARTICULI, INTERNODES, and MERITHALLI.

The tops of stems, or of their branches, are generally green, soft, and herbaceous; a great number present this appearance throughout their whole surface,—these bear the name of HERBACEOUS STEMS *(herbacei; herbacées)*; and the plants to which they belong are called HERBS *(herbæ; herbes)*; these stems do not generally last more than a year: either the plant itself perishes within this time, or the neck of the root continues to live, and shoots up new stems the following year. Usually, in this last case, the part of the stem which remains is so short, that it is customary to say that the young shoots spring from the neck; this is what we see in the Bryony, for example. Sometimes, on the contrary, the lower part of the stem becomes hard at the end of autumn, and remains above the earth, after the death of the upper part, under the form of a more or less elongated stump. This persistent part has received the particular name of STOCK *(caudex; souche)* when it is on a level with the earth; or of ROOT-STOCK *(rhizoma; rhizome)* when it is buried under the surface. The orbicular plate which forms the base of bulbs, and the neck of perennial herbaceous plants, are true subterranean stocks.

PERENNIAL *(perennes; vivaces)* Stems, *i. e.* those which last several years, are in general of a firmer, harder, and more tenacious texture than annual ones, and only present an herbaceous appearance in their SCIONS or young shoots *(turiones; scions, jeunes pousses)*; this is the name which is given to the young parts, formed during the year, which are still of a soft and greenish texture. Gardeners, and especially Roger Schabol, give to the scions the name of Buds *(bourgeons)*. Hedwig designates annular shoots by the Latin name of *Innovationes*.

Herbaceous stems may be distinguished into—

1st. FLESHY or SUCCULENT *(succulenti; charnues)* Stems, *i. e.* those the external part of which is for a long time covered with a highly-developed green parenchyma—as, for example, in the Candle Plant and *Stapelia*.

2d. WOODY *(lignosi, fructicosi; ligneuses)* Stems, *i. e.* those which have the texture and appearance of wood. When the texture is intermediate between that of wood and of herbaceous plants, the stem is said to be SUB-LIGNEOUS *(sublignosus, suffruticosus; sous-ligneuse, demi-ligneuse)*.

Woody plants are distinguished into—

1st. UNDER-SHRUBS *(suffrutices; sous-arbrisseaux)*, which send out branches from their base; they scarcely exceed half the height of a man, and do not bear scaly buds; as, for example, the Garden Sage *(Salvia officinalis)*.

2d. SHRUBS *(frutices; arbrisseaux, arbustes)*, which produce branches at their base; they hardly exceed the height of a man, and often bear buds—as the Lilac *(Syringa)*.

3d. TREES *(arbores; arbres)*, which greatly exceed the height of a man, and divide into branches at their upper part; whilst the lower, gradually denuded of them, forms a simple trunk: they are most frequently provided with buds—as, for example, the Oak. These practical and popular divisions, derived from the size and texture of stems, have no precision, since they are not founded upon anatomical differences.

We frequently find the annual stems provided with stomata; they (the stems) are of a decidedly green colour, of a more herbaceous texture, and the cellular tissue is perceptibly round. Others, on the contrary, which are of a whitish colour, and with an elongated cellular tissue, are devoid of stomata: in some we observe projecting longitudinal lines or striæ of a paler colour, formed of elongated cellules, and devoid of stomata; between these lines are green spaces furnished with these organs.

Fleshy stems have stomata when they are naturally green, as *Cactus* and *Stapelia:* it is to be observed in these cases that the leaves are absent or very small, and that the surface of the stem performs the true function of a leaf. When these stems are not of a green colour, as we see in *Orobanche*, *Cynomorium*, *Cuscuta*, &c. they never have stomata, and are always parasitical; and this is a very strong argument for thinking that *Lathrea*, *Monotropa*, and the leafless Orchideæ, are parasites, although it is very difficult, and sometimes impossible, to discover it by a direct examination of their roots.

Woody Stems are generally devoid of stomata even in their youngest state, and their external cellular tissue is sensibly elongated; we must, however, except from this rule those which have no leaves, and the green and herbaceous stems of which contain them instead; such as *Ephedra*, certain Brooms, *Casuarina*, &c.: these branches bear the stomata in the depressed lines, or between the striæ.

Stems, considered as to their general direction, present well marked differences in the various species; all those which are sufficiently solid have a tendency in general to be erect, and to rise vertically. Different circumstances in their organization or consistence cause them to vary their positions; thus, the stem is commonly said to be Prostrate *(prostratus; couchée)*, when, instead of being elevated, it lies more or less spread upon the ground: this position may occur, either in the principal stems, when they are too weak to support themselves, or in the lower branches, which, in certain plants, diverge at the base horizontally from the stem, so that the principal stem is but little or not developed; then it appears prostrate, but it is in reality the lower branches which deserve this name. In all these cases, the ends of the stem or branches have a tendency to regain the erect position; when, in doing this, and in elongating, they remain soft, they fall down again by the base, and continue prostrate; but it frequently happens that after the first period of its development, a stem so feeble in its infancy as not to be able to support itself, afterwards becomes sufficiently solid to become erect; it then has the base prostrate, and the summit erect: in this case the name of Ascending *(ascendante, montante)* Stem has been given to it.

It often happens that Prostrate Stems have a tendency, either when they are of a slightly fleshy nature, or when they have distinct nodes or articulations, or when they grow in a moist soil,—it happens, I say, that several prostrate stems have a tendency to produce roots; they are called Creeping *(rampantes)* Stems. These roots spring most frequently from near the axils of the leaves, sometimes all along the lower surface of the stem; they descend, as is peculiar to roots, vertically into the earth, and are not coloured green.

Upright stems have also a tendency sometimes to protrude roots into the air. We see this in a great number of fleshy plants, such as the different species of *Cactus* and the Crassulaceæ, or in certain foreign species of *Ficus* (Pl. 6 shows the development of roots from the lenticels of *Ficus elastica*), or especially in *Rhizophora*. These roots arise in the same manner as in creeping stems, and take a direction straight towards the ground; they are in general cylindrical and but little branched; in *Rhizophora*, where they descend from a considerable height, they form kinds of natural arcades of a very extraordinary appearance; stems endowed with this property are called Rooting *(radicantes)* by botanists.

We can, by peculiar modes of culture, excite this production of roots, even in stems which have scarcely any disposition to do so; and in this consists the art of making layers, for this is the name which is given to a part of a stem or branch, which after having produced roots, is artificially separated from the mother plant.

Layers are a physiological phenomenon, the study of which cannot occupy us here, since I have thought it necessary to make a remark upon its analogy with the natural state of rooting stems. In all these cases, whether natural or artificial, the roots, which are produced from the branches of trees, spring from the lenticels, or, very rarely, from the cicatrices of former leaves, as I have observed in *Sedum altissimum;* the origin of the roots which spring from the stems of herbaceous plants has not yet been well determined.

There are some plants in which all the branches or stems are not equally capable of producing roots; thus, for example, the Strawberry shoots from the axils of its lower leaves peculiar branches, which are called RUNNERS, *(flagellæ, viticulæ; jets, coulans).* These runners are cylindrical, devoid of leaves in a part remarkable for its length; then their extremities produce roots, and thus give origin to a bud of leaves: the runners or lower branches of *Lysimachia communis* only differ from the preceding in their not producing roots the first year, but the following year both leaves and stems. The runners of the House-leek differ only in the leaves being developed at the ends before the roots; and on account of their fleshy nature, which makes them reservoirs of nourishment, may be separated from the mother plant, and then produce roots for themselves.

Stems which, without being sufficiently strong to stand up by themselves, are not prostrate upon the ground, have a tendency to support themselves by various means upon neighbouring bodies; they are generally said to be CLIMBING *(grimpantes).* This term is applied indifferently to all the various modes by which a stem can support itself upon another body—as, for example, by means of cramps, as in the Ivy; by tendrils, as in the Pea; by sending out long spreading branches, as in *Solandra;* or by being provided with hooked hairs, as in *Galium aparine;* or by fixing themselves by means of true roots, as in *Ficus scandens*, Ferns, and climbing Orchideæ; or lastly, by twisting in a regular spiral manner, as *Convolvulus*, &c. These last bear the special name of TWINING *(volubiles)* Stems, and they deserve our attention a little longer than other climbing plants.

Most stems, even those which are perfectly upright, present a spiral tendency in their development. Thus:

1st. Trees but slightly branched, as the Fir, are frequently seen to present this direction of the fibres in a very decided manner; and it is easily seen in the woody body when it has remained for some time denuded of the bark and exposed much to the air, which, by drying the surface, causes spiral fissures.

2d. Du Petit-Thouars has remarked, that the epidermis of trees with a smooth stem, as the Cherry and *Hydrangea arborescens*, is more easily taken off in a spiral direction than in any other.

3d. The primitive disposition of the leaves of Endogens is spiral, and a great number of those of Exogens are disposed in the same way, either naturally or accidentally. In Pl. 9, I have represented a very remarkable monstrosity of the Mint, as an example of spiral development in one of the families where we should the least suspect it. Vaucher has made known a curious example of *Equisetum fluviatile*, the stem of which presented the fibres twisted in a regular spire.

Is this spiral tendency of the fibres organic or physiological? Is the fact itself general? I do not venture to affirm this; I am bound to mention these observations as connected, it seems to me, with the history of twining stems.* Some of these, such as the *Cobæa*, present, in

* This connexion with twining stems is also confirmed by a curious observation of M. Léopold de Buch—viz. that in several species, the direction of the spiral twist of upright trunks appears as constant as that of twining stems: thus, for example, according to this observer, the Horse-chestnut and Common-chestnut turn in contrary directions.

a high degree, this spiral torsion of the fibres of the stem; it only commences at some distance above the neck.

Twining stems may be erect or prostrate in their young state; but after some time they elongate much, and twist themselves spirally; if they do not meet any body capable of serving for their support, they fall again, or sometimes twine round one another, so that some individuals of the same species, or some branches of the same individual, mutually support each other; if they meet a suitable support, they twine themselves round it, in a direction constant in each species—from right to left, as in the French Bean—from left to right, as in the Hop. This direction is determined by supposing oneself placed in the centre of the spire, with the stem turning round his own body. The cause, whether physical or anatomical, of the twining disposition of several stems, and the peculiar direction which affects each, is perfectly unknown. Some have thought that it is connected with the daily course of the sun, and its action upon the vegetation. Although it would be very extraordinary for one cause to produce opposite effects, yet we must not reject this opinion; and the ingenious Dr. Wollaston conjectures that it might be verified, if, by observing individuals of the same species, with twining stems, in the two hemispheres, it were carefully remarked whether they turned in the same or in opposite directions;—an observation which is very simple, and deserves to be recommended to travellers in the southern hemisphere.

Although it may be the cause of it, I will add that in several plants this disposition remains throughout their whole lives, however more or less woody they may be; as, for example, *Wisteria fruticosa* and *Periploca græca*. There are, on the contrary, some plants where this tendency is only visible in the young shoots, and disappears in the woody branches or trunks, as is seen in several species of *Convolvulus* with woody stems.

Article II.—Of the Branches.

Stems are said to be Simple *(simples)* when they have no branches or ramifications: the greater number, on the contrary, are Branched *(rameuses, branchues)*, that is to say, divided into branches which bear the leaves and flowers; for the branches which only bear flowers (except in plants devoid of leaves, as in *Orobanche ramosa*,) are only considered as peduncles, and their presence does not prevent the stem from still being designated as simple.

The branches *(rami)* always spring from the axils of the leaves *(axillares)*, or very near them, either a little above *(supra-axillares)*, or on one side *(extra-axillares)*. In some plants, as the *Geranium*, they arise opposite the leaves *(oppositifolii)*; there is then almost always a fixed connexion between the primitive position of the branches and that of the leaves; but after some time this regularity of the primitive position is rarely to be recognised, on account of the great number of branches which die in their infancy. If we take a Pear tree, for example, we shall see a small bud in the axil of each leaf: all these buds commence by growing a little; but that, or those, which, by some peculiar cause, increase the most, soon attract all the sap, and the others therefore perish, sometimes being still in the state of buds, at others having already formed little branches: such is the general cause of the irregularity of the old branches, compared with the regularity of their origin. This irregularity only extends, however, to a certain limit in each species.

The young branches almost always have a tendency to take a direction upwards; but as they increase in size, they become a little more horizontal, either on account of their weight, or because their extremity, always seeking the light, is obliged to bend towards the base in order to extend beyond the upper branches. But if the angle formed by each branch varies according to the age of it in most trees, it is pretty constant in each species, and presents great differences in different plants when compared together. Thus, when the angle is very acute, we say that the branches are ERECT *(droits, serrés)*, as in the Poplar, and the whole tree is said to be PYRAMIDAL *(pyramidalis, fastigiatus; pyramidal)*; when the angle is almost a right angle, if the branches are placed opposite to one another, we say that they are STRAGGLING *(rami divaricati; divergentes;* if they are scattered, we simply call them SPREADING *(patentes; étalées, ouvertes)*. It happens in some individuals, that the angle, instead of being acute, is obtuse, and then the branch is directed towards the base. We see this in certain varieties of *Gincko biloba* and *Fraxinus excelsior*; they are commonly called by the name of the *Weeping* or *Drooping* Gincko or Ash; but we must not confound them with trees which, as the Weeping Willow, have their branches so long and weak that they fall down at their extremities. The former have the branches TURNED BACKWARDS *(retroversi; rebroussés)*, that is to say, directed downwards from their origin; the latter have them PENDULOUS *(penduli; pendans)*, that is, erect at their origin, and afterwards falling down on account of their weight.

In general, the lower branches are longer than the upper, because they are always older; this difference in length is scarcely perceptible in trees with upright branches, but is much so in those with spreading ones, and is usually in proportion to the angle which the branches form with the trunk.

When the lower branches are not able to extend, as happens in forests, or in certain trees by the natural effect of their growth, they perish by degrees, and thus arises the denudation of the trunk of trees.

Generally, the lower branches of large trees are parallel with the ground; and this is true, not only when they grow on horizontal ground, which explains itself, but also when they are placed upon a hill; in this case the lower branches of the cyme remain parallel with the surface. This parallelism with the ground is also found in individuals of which the trunk itself is oblique to the horizon. Dodart, who first insisted upon this popular observation (Acad. Science, 1699, p. 60), remarks that the roots almost always spread out parallel to the surface; it results then that the plane of the branches is parallel to that of the roots: in order to explain this, he supposes that the fibres of plants have a determined length, and that being continuous from the extremity of the root to that of the branch, it is necessary, to preserve the same length, that they should form angles. But we cannot maintain the principle of the fixed length of the fibres, for it is sufficient to expose a branch to favourable circumstances, to make it grow indefinitely. This parallelism is explained, on the contrary, very easily, by the proportion which all the branches and roots generally preserve during their growth.

It is a pretty constant observation, that a large branch corresponds to a large root, and *vice versâ;* and this is equally true, whether a root, placed in favourable circumstances, causes the increase of the branch which is above it, or the branch, similarly situated, makes the root which corresponds to it to be developed. But in trees which grow upon hills, the two sides of the root are not in an equal position ; those on the upper ought not to grow as much as those on the lower side, because they cannot go above their level, and at a certain depth they do not feel the beneficial influence of the atmosphere; those of the lower surface, on the contrary, ought to grow with the greatest facility; consequently, the branches of the lower side will elongate more than those of the upper: but the longest branches are those which, by their weight and tendency towards the light, are obliged to spread out more; the lower branches then will be more spreading than the upper, whence results this rude parallelism of the branches with the ground: and in fact it is only apparent in trees with spreading branches, and we always remark that the upper side of the cyme is smaller than the other.

Section II.

Of the Stems of Exogens or Dicotyledons.

The stem of Exogens presents an organization more complicated than all others; and if I commence by examining this class, I do so because it is much better known than the two others; because the multiplicity even of its organs causes each to perform a function more easy to describe; and because, containing moreover all the trees of our climate, it naturally presents itself to our notice.

We meet with, at first sight, two very distinct parts in the stem of Exogens—viz. the Woody Body, or Central System *(corps ligneux, ou systême central)*, which is placed in the centre, and forms the principal part of the trunk; and the Cortical Body or System (*corps ou systême cortical*), or the Bark, which surrounds the woody body. Each of these parts presents two portions, which are distinct, and placed in an inverse direction to one another. The parenchymatous part of the woody body, the CENTRAL PITH (*moelle centrale,*) or the PITH *(moelle)* properly so called, occupies the centre; and the fibrous part, which composes the WOOD *(bois)* and the ALBURUM *(aubier)*, is disposed in layers around the pith. On the contrary, in the bark, the parenchymatous part, or the CORTICAL PITH *(moelle corticale)*, which bears the name of the CELLULAR ENVELOPE, *(enveloppe cellulaire,)* is found on the outside; and the fibrous part, which includes the CORTICAL LAYERS, *(couches corticales,)* and the LIBER *(liber)*, is in the interior. The woody and cortical bodies, then, are two parts organized in an inverse direction to one another. We shall first study each of these organs considered separately, in order afterwards to give some general observations upon them taken together.

ART. I.—OF THE CENTRAL OR WOODY SYSTEM.

§ 1.—General Considerations.

THE Central System or Woody Body of a tree, taken collectively, is composed of an indefinite number of very elongated cones, inserted upon one another; and which, when cut horizontally, present so many concentric layers. Each of these layers is composed, as Dutrochet has well established, of two principal parts;—1st, a band of cellular tissue, situated on the inner side; and, 2d, a band of fibres, or bundles of vessels and elongated cellules, placed on the outer side. Consequently, the innermost or oldest layer presents the band of cellular tissue under the form of a central cylinder; this is what forms the pith properly so called; and all the following layers present this cellular tissue under the form of a more or less narrow belt, which separates the belt of fibres of the preceding year from that of the present. All this apparatus is traversed, from the centre to the circumference, by laminæ of an analogous nature to the pith, which, in a transverse section, have the appearance of the spokes of a wheel, or the hour-lines of a dial, and have received the name of MEDULLARY RAYS *(rayons médullaires)*.

We now proceed to examine, successively, these different parts.

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§ 2.—Of the Central Pith.

If we cut transversely a stem of the Elder, for example, or of any other Exogenous tree, we observe in the centre, a canal, usually angular, or nearly cylindrical, to which Grew gave the name of the Medullary Cavity, and which is generally called the MEDULLARY CANAL *(canalis medullaris; canal médullaire)*. This canal is full—at least in the infancy of the branches—of round cellular tissue, to which the name of the PITH *(medulla; moëlle)* has been given, because it occupies the centre of the wood, as the marrow fills the central cavity of the long bones of animals.

The cellules, of which the pith is composed, are usually more regular, larger, more dilated, and of a more spongy texture, than those of the rest of the tissue. In several plants this cellular tissue composes the whole of the pith: in a large number we find a circular row of fibres, isolated from one another, and dispersed in the pith upon the outer border of the canal. Hedwig designated them, in his first works, by the name of *Vasa fibrosa;* and I called them MEDULLARY FIBRES (*fibræ medullares; fibres médullaires).* Lastly, in a small number of Exogens, these same fibres, instead of being arranged circularly, are scattered throughout the whole pith; we remark this easily in the stem of *Ferula communis* (Pl. 2, fig. 3); and Mirbel has also observed it in that of the Marvel of Peru. The stems of *Ferula* have the pith very large, intermixed with scattered fibres, and the woody body scarcely visible, as happens in most annual stems; so that, at first sight, one would be inclined to take them for Endogens. These Medullary Fibres sometimes become coloured, when the young stems are soaked in coloured water, which shows that they give passage to the sap: the cellular part never becomes coloured in these experiments. This was likewise the result, both from trials by the Jesuit Serrabat, who, under the name of Delabaisse, has published a Dissertation upon the circulation of the Sap, and from my own experiments upon this subject.

The MEDULLARY SHEATH *(vagina medullaris; étui médullaire)* is a woody layer which immediately surrounds the pith. Du Petit-Thouars observes, that it seems to form a cylinder continued from the top even to the bottom of the tree; but that, like the pith, it is composed of as many parts as there are shoots. It is a layer of woody fibres, in which are found Tracheæ, capable of being unrolled, not only in the first year, but, as Mirbel and Du Petit-Thouars have observed, in very aged trunks. In several trees this Medullary Sheath preserves, even in the old branches, a green colour, which shows that it is still endowed with vitality; Sénebier has seen this in *Phytolacca,* and I have remarked it also in the Chestnut, the *Catalpa*, &c. It appears that Hill was the first who observed this organ; he has named it *Corona*, and regards it as the principal agent of vegetation. In several trees, and especially in those with alternate leaves, the pith forms a continuous canal from one end of the tree to the other, but plainly contracted at each new shoot. In others, on the contrary, such as the Chestnut, the Ash, the Vine, which have all opposite leaves, the pith is interrupted, at each node or annual shoot, by a kind of woody partition. The same thing takes place, in a still more evident manner, in articulated stems; for example, in that of *Cacalia articulata*.

The mass of cellular tissue of the pith varies much in different species: herbs and shrubs have generally more than trees. The *Ferula* has it the largest that I have ever seen, in proportion to the diameter of the stem. Among trees, those with very hard wood seem in general to have less than others: the Ebony *(Diospyros Ebenum)* and Lignum Vitæ (*Guiacum officinale*) have very little; the Pear and Oak a little more; the Elder, the White Thorn, the Fig, the Sumach, and the Chestnut, have still more.

The size of the cellules of the pith is also very variable, if different species are compared together. The Elder and Thistle have both a large quantity of pith; but in the former it is composed of a great number of very small cellules: in the latter, of a less number of much larger ones.

The Medullary Canal in young shoots, instead of being cylindrical, frequently presents regularly placed angles. These are connected with the disposition of the leaves upon the branch. This interesting observation of Palisot de Beauvois and Du Petit-Thouars, has not been applied to a sufficiently large number of species to enable us to derive from it any important conclusions; but it well deserves further attention.

But in order to form a just idea of the pith, it is less important to study the variations which it presents in different plants, than to follow its whole history in a single individual; this is what we shall try to do in a rapid manner.

The pith of a very young shoot is a regular cellular tissue, continuous, or strictly contiguous in all its parts (one entire piece; Grew, p. 120), and full of juice, which renders it soft, and gives it a green herbaceous colour. As vegetation proceeds, the cellules of this tissue become empty, and dry up more or less quickly, according to the species, and take a white, or, in some trees, a brownish tint, and then, in different stems, one of the three following phenomena takes place: if the pith is tolerably firm, and as its cellules may be small, or at least capable of being stretched without tearing, as, for example, in the Elder and Chestnut, it then dries up gradually, and, at the end of the first year, takes the appearance of a dried cellular tissue, but preserves all its original form. In some trees, as the Oak, the cellular tissue of the pith solidifies, and becomes hard and compact, but without losing its primitive form. If the pith has large cellules, or a tissue which is not capable of extension, it is then broken transversely, or longitudinally, according as it is drawn by the elongation or enlargement of the branch. Thus in certain stems, such as those of the Walnut, the common Jessamine, &c., the elongation of the young shoots breaks the pith transversely, and forms, at the end of the first year, little transverse disks of dried pith, separated by so many disciform cavities.

If, on the contrary, the increase in diameter is proportionally greater than the elongation, the pith then splits longitudinally, as in the Thistle, *Phlomis,* and, in general, in herbaceous stems, in which the medullary canal is hollowed out into a longitudinal tube, either in the first year, or sometimes a little afterwards, when the first woody layer begins to dilate.

But what becomes of this pith after the first year? This question is, in reality, more curious than useful; for the pith, being dried up and inert, does not appear to have any function. Grew was the first who advanced that it was smaller in a branch of two years' growth than in that of one; that it was still more diminished in one of three years; and thus it continued to decrease as it advanced in age: whence he appears to infer that it vanishes after some time. Duhamel positively asserted this disappearance of the pith in old trunks; "by degrees," he says, "the medullary canal diminishes in diameter; and in large trees (those same which, in their young state, have most pith), neither the canal or medullary substance are any longer to be seen." (Phys. Arb. i. p. 37.)

Mustel also admits this *disappearance of the dried pith,* and the formation of new woody layers in the interior of the medullary canal (*Traité Végét.* i. p. 62).

Mirbel also says, in his Histoire des Plantes, Vol. I. p. 194, that an interior liber (of which he admits the existence) is developed, and that *the pith completely disappears.* Almost all modern authors agree with this opinion. Sénebier appears to admit as a certain fact this disappearance of the pith, since he searches for means to explain it; but he appears to believe that this phenomenon is not general in all trees. Varennes de Fenille has been the first to remove the doubt from the assertion of Duhamel, by saying that he possesses two specimens which prove the contrary. But in these later times, Mr. Knight (Philosophical Transactions, 1801) and Du Petit-Thouars appear to me to have brought to light, in the most evident manner, a contrary proposition to that of Duhamel; that is to say, the non-disappearance of the pith in old trunks. Their testimony is confirmed by Desfontaines, Jussieu, and Labillardière, who have found the pith in old trunks of the Hawthorn, Beech, Elder, Oak, and Elm; and I have myself verified it in several trees, such as the common Chestnut and the *Ailanthus*.

How then is it that a question, in appearance so simple as that of knowing whether or not there is any pith in old trunks, has been for so long a time a subject of doubt and uncertainty? It is that it has not been sufficiently remarked, that all young branches have not a uniform diameter, and that their medullary canal is in proportion to their size: thus, for example, the strong young branches of the Elder have a pith, the diameter of which is at least double that of the fruit-bearing branches. Du Petit-Thouars has also remarked, that in the young branches of this tree, the diameter of the pith varies in different proportions, from one to nine lines. These variations are found in almost all trees; so that if we were to examine a very large young shoot, and afterwards a branch proceeding from a slenderer young shoot, we should decide that the pith has diminished, exactly as we would decide the contrary if we compared a very slender young shoot, with a branch produced by a very vigorous one. The very hard trunks in which the medullary canal is scarcely visible, proceed from branches which, in their young state, had an extremely small pith. Those with a visible pith proceed from branches which had, in their young state, an abundant pith; and the same tree sometimes presents these two kinds of branches.

If so simple a fact as the existence or the disappearance of the pith in old trunks be disputed, we know that, with greater reason, we cannot agree with regard to the use of it. The older naturalists, and some modern ones, who believe in the sensibility of plants, regarded it as being analogous to the brain; but can this be a brain which is obliterated each year, and is absent in so many plants? Others, as the similitude of the names indicates, have compared it with the marrow of the bones of animals; but the marrow is permanent and continues fresh, and the pith becomes obliterated. Hales and Mustel compare it with the substance which fills the young feathers of birds, which dries up when they have increased in size, and becomes, like the pith, a receptacle of air. Others have compared it with the heart, lungs, stomach, &c.; but let us quit these useless comparisons, and endeavour to study this organ considered by itself.

Cesalpinus and Linnæus thought that the pith gives origin to the pistil; they have been induced to form this opinion from the similarity of situation which the pistil and pith occupy in the flower and the wood. But all Endogenous plants, in which there is no central pith, have also a pistil, which is likewise in the centre of the flower.

Magnol believed that the pith is destined to elaborate the more perfect juices, not those which are necessary for the simple nourishment of the wood, but such as are made for the fruit; and he tries to prove his opinion by mentioning some trees with an abundant pith which bear much fruit. But the branches which are not destined to bear fruit, are not provided with less pith than the fruit branches; several Exogens might be mentioned which bear much fruit, and have very little pith; and, lastly, in most trees, the pith dries up before the time of flowering.

It was, doubtless, an idea analogous to that of Magnol which has led gardeners to say that in order to obtain stoneless fruits it is sufficient to destroy the pith of the trees. Duhamel, who performed this experiment, found that if the branch survived this operation and bore fruit, these fruits had stones as usual. Finally, the presence of the pith in branches which are not destined to bear flowers, sufficiently proves that the use of this organ is not connected with the flowering.

Borelli and Hales attribute to the pith a powerful action in vegetation; they think that this spongy substance, placed at the extremity of the branches, attracts the moisture; that it adheres there strongly; that the sun endeavours to separate it; and that from this action results the elongation of the fibres: this explanation is so far removed from the more simple notions of physiology, that it is needless to refute it.

Malpighi thought that the sap ascends through the wood, that it is carried into the pith through the medullary rays, and that there it receives a peculiar elaboration. Plenck, who adopts the idea of Malpighi, adds that the pith is a receptacle of the nourishment which the young shoot absorbs in the time of drought. These last authors came very near the truth; but they have too much neglected an essential circumstance, viz., that the pith has no physiological life, action, or existence, but during the first period of the development of the bud; and that, when this epoch has passed, it becomes flaccid and useless; it is then a receptacle of nourishment destined to support the young shoot until it has developed its leaves, when it can obtain it for itself. It is, if I may thus venture to express myself, the *Cotyledon of the bud*, provided that this expression is employed in connexion with the physiological use of the organ, and not with its organographical function.

Such is the manner in which, from general facts, I have represented the use of the pith in the public course of Vegetable Physiology which I gave in the Collége de France in 1802. Since then I have had the satisfaction of seeing a distinguished observer arrive at the same conclusions, and support them by a very curious fact. Du Petit-Thouars has remarked that the *Lecythis*, which is certainly an Exogenous plant, germinates without apparent cotyledons,* but that its first shoot has a very large pith, which serves to nourish the young plant, and thus performs, physiologically, the function of the cotyledons, as the ordinary pith does for the buds. After it dries up (if it be of any use, which is very doubtful) it can only, as Grew has thought, become a receptacle of atmospheric air. In the article upon the Medullary Rays, we shall speak of the analogy of the pith with the cellular envelope, and the rays which unite these two organs.

All that we have said of the Central Pith, applies, with slight differences, to those of following years, each of which, under the form of a Medullary Zone, represents the central one; it results from their position that their form is very different, but their analogy of nature is perceptible. We may be assured of this by examining certain trees, such as the *Rhus Typhinum*, in which the pith is coloured, and where we observe a similar colouring to that of the centre in those of following years. These last are never broken as the centre one, owing to their position; but they follow, moreover, the same changes; at first they are fresh and full of juice, and finish by drying up or solidifying. When a small piece of wood is macerated, its cellular parts, never being of the same density as the fibrous zones, are first changed, and the latter are then obtained, more or less detached from one another, by the disappearance of the intermediate cellular tissue.

* The true cotyledons of this genus appear to be so intimately joined together that they cannot be separated, and form an undivided embryo, similar to that of Monocotyledons. (See Book III. chap. iv. sect. iv.)

§ 3.—Of the Woody Layers of the Wood and of the Alburnum.

Between the central pith and the bark are found concentric layers or zones, which bear the name of the Woody Layers *(strata lignea, involucra lignea,* Malp.; *couches ligneuses).* The assemblage of these layers forms that which is commonly called the Wood *(bois)* of the tree; that which Malpighi calls the Woody Portion *(lignea portio),* and others the Woody Body *(corpus ligneum; corps ligneux),* or Central System *(systême central).* Grew designates it under the name of the *Main Body.* This part, which forms the solid base of trees, presents in old trunks two different appearances; 1st. The central layers, which are harder, more coloured, and evidently older than the external; these form that which writers call the Heart-wood; that which naturalists designate under the name of Wood *(lignum; bois),* or Perfect Wood *(bois parfait)*; and that which Dutrochet has recently proposed to call Duramen. 2d. The external layers are more tender, of a white colour, and evidently of a later date than the preceding; they form the part which has received the name of the Alburnum *(alburnum; alburna,* Malp.; *aubier)* on account of its whiteness, or of the Imperfect Wood *(bois imparfait),* because of its age, compared with the Perfect Wood.

In order to comprehend well the difference which is found between the Wood and the Alburnum, it is necessary to anticipate a little that which we shall hereafter say upon the formation of the Woody Layers. Around the Medullary Canal there is formed, during the first year, a layer which immediately surrounds this canal;

in the second year, a second layer, placed immediately on the outside of the first, surrounds it again on all sides; and, in like manner, year after year; the only essential difference which is observed between the first and following layers, is that the first presents, even at an advanced age, tracheæ in a state capable of unrolling; and that in the following, even in a young state, there are only found striped or dotted vessels. Each year the vessels already formed acquire more hardness and firmness, because the juices which traverse them are continually depositing small particles in them. It happens that after an indefinite number of years the layers are unable to take any farther consistence; those which are still sufficiently young to acquire new particles, form the Alburnum; those which cannot acquire more, the Wood. We know, from this plain and simple exposition of the fact, that the alburnum is less tenacious, firm, and compact, than the wood; we know that the different layers of the alburnum can present different degrees of firmness according to their age; whilst those of the wood, having arrived at their maximum of hardening, ought to present a more homogeneous mass, although all of different ages.

In some trees, and especially in those which are not very hard, the line of demarcation of the wood and alburnum is hardly perceptible; we see this in the Poplar, the Willow, the Chestnut, the *Bombax*, &c.: on the contrary, in hard woods, this line is readily distinguished by the hardness and colour of the organs; thus, in the Ebony, the wood is, as every one knows, perfectly black, whilst the alburnum is white (Pl. 5, fig. 2); in *Cercis Siliquastrum* the wood is yellow and the alburnum white; in *Phillyrea* the wood is brownish yellow, the alburnum white; but in this last species the perfect wood is only found in very old trees; and I have remarked as many as fifty layers of the alburnum in *Phillyreas* about 200 years old, which I have been obliged to cut down in the part of the Garden of Montpellier planted by Belleval.

We easily understand that in trees of different species there must exist numerous varieties in the number, thickness, hardness, and colour of the layers of the alburnum, compared with those of the wood; but in each species itself, some differences are also found in different individuals. Thus, in general, trees which grow in damp places, or during wet seasons, have more alburnum than those which grow in dry places, or during dry years. Duhamel assures us that in different stunted oaks he has counted from seven to twenty-five layers of the alburnum.

The relation of the thickness of the alburnum to the wood varies in different species and different individuals, not only from the preceding causes, but, moreover, from the age of the tree. Thus, the alburnum is equal to the wood in an oak six inches in diameter; it is as two to seven in a trunk of a foot; as one to nine in one of two feet, &c.; still these proportions given by Duhamel are very variable. Mustel has observed that different parts of the same layer of the alburnum may be transformed into perfect wood at different periods; thus he has seen some Oaks which had, on one side, fourteen layers of the alburnum, on the other, twenty; or, on one side seven, on the other twenty-two, &c. The layers of the alburnum are almost always thicker on the side where they are less numerous; that is to say, in other terms, that when a root meets a good stratum of earth, it nourishes the corresponding part of the tree more abundantly. Those parts which are most nourished have the woody layers thicker, and they arrive more quickly to the state of perfect wood, whilst the roots which fall in with poor strata badly nourish the corresponding parts; and, consequently, these have the layers thinner, and they remain a longer time before they attain their complete hardness.

All workmen know very well that the alburnum is less solid than the wood, and take care to separate it from the latter when they use it for building purposes, &c. Buffon, who performed with Duhamel some important experiments upon this subject, found that in the Oak the difference of solidity of the alburnum and the wood, is as six to seven. But the principal cause for which the alburnum is carefully rejected from the wood in building, is that on account of its looser tissue it is more liable than the latter to be affected by moisture, worms, and insects. We often find stakes placed in wet situations, with the alburnum either entirely decayed, or perceptibly changed, while the wood is still very sound. In order to remedy this inconvenience, Duhamel and Buffon proposed, from their own experiments, to rind trees a year before they are cut down; by this the tree is prevented from forming a new layer of the alburnum, and the nourishment which would have been employed in developing this new layer, being distributed to the layers of alburnum already formed, causes them to become almost as hard as perfect wood. This method ought to be practised with timber destined for ship-building in particular, because this hardened alburnum is less liable to be attacked by the *Teredo*; it is, however, rarely practised; and it is asserted that it has the inconvenience of rendering the wood more brittle.

If we except the medullary part, each layer, whether of the wood or alburnum, is composed of porous or striped vessels, intermixed with elongated cellular tissue; this is so much the more elongated the harder the wood is destined to become. The vessels are in general striped transversely, in soft wood, and dotted in hard. The only organic difference which exists between the wood and the alburnum is, that the interior of the cellules, and perhaps of the vessels, is usually encrusted in the former, whilst it is empty, or filled with less solid juices in the latter, which, consequently, has the membranous tissue more transparent. Dutrochet has proved that the hardness of different woods, and of the wood and the alburnum, results from the nature of the juice deposited in their tissue, and not from the tissue itself, which appears identical. By heating Ebony in nitric acid, the black matter is dissolved out, and the tissue remains of a pearly white colour. It is the same with all coloured woods: the tissue of the Box and Poplar, although these woods differ much in their density, becomes similar when the matter with which it is filled is dissolved out by nitric acid.

Each woody layer, in Exogenous trees, is the product of the vegetation of one year; but Duhamel thinks that it is not formed all at once: he says that each layer is itself composed of an indefinite number of little parallel layers, or rather, that it is continually growing during the whole year, but with more or less activity at different seasons. Duhamel has demonstrated his opinion by an apparently simple experiment;—in the beginning of the spring he raised up the bark of a young tree, placed a thin piece of tin between it and the wood, and laid it (the bark) back again upon the wound; he repeated this every fortnight, as long as the bark could be separated from the wood; at the end of the Autumn, having cut down the tree, he found that each plate of tin was covered by a quantity of wood, which was larger according to the length of time it had been placed there. This experiment, although in appearance conclusive, may conceal several errors; and it is likely that it was made with but little nicety, for no one has been able to repeat it in the manner mentioned.

It is to be remarked, as we have before observed, that there is no real interval between the layers; but that that which appears as such after maceration is nothing but round cellular tissue. Dutrochet appears to me to have proved that this zone of cellular tissue represents for each woody layer, that which is the pith for the central one, and that thus an entire woody body is formed of bodies resembling each other, except the differences caused by their position; others think that this zone of round or elongated tissue, may be produced by the slow growth during winter; the cellules would have, according to them, the time then to become round and developed in every direction; whilst, when the growth is rapid, they will be elongated, and, as it were, dragged along by the increase of the vessels.

It would result from this manner of considering the zones which separate the annual layers;—1st, That this separation ought to be so much the more perceptible as the alternations of the vegetation (those which are caused either by the fall of the leaves or by the alternation of the seasons) are more distinct; this is not observed in comparing trees of the North and the South. 2d, That an accidental stagnation of the vegetation caused, during summer, by a return of cold, or by any other cause, ought to produce a cellular zone analogous to that of the winter; just as a very mild winter might cause the annual zone almost to disappear. Hill asserts that, in many cases, two distinct layers are formed during the year; the one owing to the sap of the spring, the other to that of the summer: he calls these the layers of the seasons. Adanson indicates, on the contrary, that the layers of certain years are often mingled together, from observing that Elms of a hundred years old, cut down in the Champs-Elysées, presented from ninety-four to a hundred layers.

Notwithstanding these slight anomalies, which result perhaps from this—that all the trees of a plantation may not be exactly of the same age, it appears certain that the number of layers affords the means of knowing how many years old a branch or tree may be,—the number of concentric zones in a transverse section indicates the number of years which have elapsed since the formation of that part. In order to know the age of the whole tree, it must be sawed off exactly at the neck; but this part is not always easily recognised with precision in very old trunks; and this is a slight source of practical error, but which does not affect the principle upon which we judge of the age of trees.

All the layers of a tree are not of equal thickness, neither with regard to each other, nor in their different parts; and this is easily known, since each is the product of the growth of a year. The woody layer will necessarily be more or less thick, according as the year may have been favourable or unfavourable—according as the roots of different lengths may have found a good or poor stratum of earth—according to the care taken of the tree, &c.

Besides these causes of accidental anomalies, the age alone of trees influences the thickness of the layers in a regular manner. I have observed, in this point of view, very old Oaks cut down in the Forest of Fontainbleau; the thickness of their woody layers goes on augmenting until the thirtieth or fortieth year; from the thirtieth to the fiftieth, or even sixtieth year, it slightly diminishes; but between the fiftieth and sixtieth the thickness of the layers becomes very regular, and probably continues so until the death of the tree; at least, the trees upon which I have made this observation, were, for the most part, between two and three hundred years old; the oldest of all was three hundred and thirty-three. After sixty years an oak increases from about eight to ten lines in diameter in ten years; and from two to three inches when it is between twenty and thirty years old. Finally, these observations are necessarily subordinate to the difference of species, soils, seasons, and cultivation. They would seem to indicate that it would in general be profitable in regular cuttings to cut down every thirty years, rather than every twenty years, since it is from the twentieth to the thirtieth that the trunk of oaks increases the most.

Not only are the layers unequal with regard to each other, but their thickness is not often the same throughout their circumference. Malpighi was the first who carefully observed that the pith seldom occupied the exact centre of the trunk; or, what is the same thing, that the concentric layers are often larger or more numerous on one side than on the other; this phenomenon has been designated by the name of EXCENTRICITY *(excentricité)* of the woody layers. Among the ancients, some asserted that the pith was nearer the bark on the south side; others said that this was the case on the north.

Neither the one nor the other have omitted hypotheses to explain this fact; several said that it was a means of knowing the situation of the tree in the forest, &c. &c.; but all the marvellousness has vanished with an exact observation of the fact. Duhamel and Buffon proved that the excentricity had no connexion with the position of the tree relative to the points of the horizon, but with its purely local situation. When on one side of it a good stratum of earth, or a place free from all other roots, is found, those roots which are directed there receive more nourishment, furnishing more to the corresponding part of the trunk, which increases most on this side. In like manner, if one side of a tree has its branches more exposed to the action of the air and light, the corresponding part of the trunk grows more than the opposite. It is by the union of these two causes that all trees in forests, or avenues, grow more on the external than on the internal side. Such is the very simple explanation of the excentricity of the pith, which, in reality, is only due to the inequality in the thickness of the layers. We will hereafter revert to what takes place where the numbers of the layers are unequal on the two sides of the tree.

If all that I have said about the woody layers has been attentively followed, it will be seen that each of them is, during its first year, a kind of very elongated cone, which surrounds the pith; that during the second it forms a second cone, which surrounds the terminal prolongation of the pith, and which is prolonged at the base in such a manner as to cover over the cone of the first year; and thus cone after cone is formed in succession, until the destruction of the trunk. It evidently results from this, that each cone, or woody layer, only increases during the first year of its life; and that it is afterwards covered over by subsequent cones, and is, as it were, shut up by them in such a manner as not to be able to lengthen or thicken any more: it remains, after some years, in an almost passive state, and does not seem any longer to form part of the living organs of the plant. It results from this state of things, that the woody layers serve successively as coverings to each other; and if one of them has received any injury—as the action of frost, having letters cut in its tissue, or cavities hollowed out in its thickness, having nails driven into it, &c. &c.—all these injuries, covered by subsequent layers, may be again found after any number of years: experiments have demonstrated this, and it serves to explain several facts to which marvellous ideas would be attached. Thus the layers of the alburnum, being full of sap, are liable to be frozen when the cold is very intense. When this accident takes place, and the frost does not reach the liber and the alburnum, the tree continues to live; the frozen layer is covered over by a sound one—afterwards by several others; and thus covered, it is found in the centre of trees: this accident is named in French, *Gélivure.* We can, by counting the number of layers formed since the accident took place, know in what year it happened. Thus, in 1800, I had cut down in the Forest of Fontainbleau, a trunk of a Juniper *(Juniperus communis)*, which was found to present, near its centre, a layer which had been affected by frost, covered over by ninety-one woody layers, and which dated therefore from the severe winter of 1709. (Pl. 4, fig. 2.*)

An inscription written upon the trunk of a tree, and which penetrates to the alburnum, is covered over by new woody layers, and may be found entire as long as that part of the trunk remains so. It was thus that Reisel found, in 1675, some capital letters in the middle of a Beech; that Mayer, in 1688, found in the woody body of a Beech a kind of sculpture representing a gallows, and a person hanging; that Albrechti, in 1697, found in the same tree the letter H, surmounted by a cross; that Adami found, under nineteen layers of the alburnum, the letters J. C. H. M. It is thus that in certain trees in India there have been found inscriptions in the Portuguese language, which had been written there some centuries before, when the country was discovered by those navigators. It is thus that different spots, or regular stars, have been artificially formed in

* The extraordinary contraction observed in the trunk was caused by its growing between two rocks.

the middle of several trees. Two Mémoires by Fougeroux de Bondaroy, inserted among those of the Académie de Paris for 1777, may be particularly consulted upon this subject.

When any accidental cause, as the hand of man, the teeth of animals, or simply a morbid change, hollows out a cavity in the alburnum, the orifice of which is sufficiently narrow to be covered over by the subsequent woody layers, the cavity is preserved entire, as well as any objects shut up in it. I have seen, for example, in the middle of a large piece of Oak, which appeared perfectly sound, a cavity partly filled with nuts and acorns, which had probably been carried there by dormice or squirrels, before it was covered over by new woody layers. In the same manner bones, stones, &c., are found in similar cavities.

When a nail is driven into a tree, so as to reach the alburnum, it remains fixed, and, by degrees, the new woody layers which are formed around it surround its base, so that it appears as if it had been driven into them; sooner or later it is entirely covered over: it is thus that we find nails and other instruments, or the horns of stags, infixed, or completely sunk, in the wood of Exogenous trees. It is by the same process that the base of the Mistletoe appears each year to sink into the tree, because the woody layers rise up around it. We shall find a more general application of these principles when we come to the Formation of the Branches. We shall see by-and-by, that phenomena diametrically opposite to those we have been describing, take place in the cortical layers.

As a consequence of the preceding facts, and of the mode of nutrition of Exogens, it happens that if the stem of a tree of this class be surrounded by a cord or wire, the trunk, by growing, becomes contracted here;

by degrees the tree increases in size, especially above the cord, so that it appears as if it were buried in the tissue. It is in this manner that climbing shrubs often kill the trees around which they twine, as may be seen even in our climate; as, for example, in the *Periploca Græca*, or *Wisteria frutescens*. We shall see, in speaking of Endogens, that similar phenomena with them are impossible.

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§ 4.—Of the Medullary Rays.

If the woody stem of an Exogen be cut transversely, we remark lines springing from the pith and radiating to the bark, like the lines on a dial, or the spokes of a wheel. Grew, who first observed them, called them Medullary Insertions; they have since been called MEDULLARY RAYS *(radii medullares; productions, prolongemens, or rayons médullaires)*; this term is more applicable, because it describes their position without affirming their origin. Between the complete rays are perceived some half ones, which arise from the centre, and appear to stop before they reach the circumference; some authors call them MEDULLARY APPENDAGES *(appendices médullaires)*. Most frequently we see some rays which do not arise from the centre, but from one of the medullary zones of which each annual layer is formed. It results from this production of medullary rays from each of the annual zones, that their number is much larger in the layers of the circumference than in those of the centre. The medullary rays are not simple processes, but radiating and interrupted vertical lamina, directed towards the circumference; we can be assured of this by making a vertical or oblique section. We are thus enabled to follow them through more or less of their extent. They form the reddish spots which are seen upon planks of Beech or Oak cut obliquely. It is in this manner that is made what workmen call Dutch Oak, which was formerly thought to be a distinct species, but in reality it is only produced by art.

All the medullary rays are composed of cellular tissue, elongated horizontally, and moderately compact. It is evident that they establish a direct communication from the centre to the circumference, or from the circumference to the centre; but in no case are coloured juices ever seen passing through them.

The continuity of the medullary rays from their origin to the circumference is very well observed when we examine wood which is rather soft; such as, for example, the Mistletoe, or certain fleshy plants. One is sometimes tempted to believe that they are continued even into the bark; and this opinion has been maintained by several naturalists. Some have spoken of the medullary rays of the central system as being continuous with those of the cortical; others as being distinct. Mirbel and Dutrochet have given great weight to this last opinion; and if it be admitted that the two systems are essentially distinct at their origin, we are obliged to conclude that in the cases where the rays seem to pass into one another, it is only the contiguity, and not the continuity of their extremities.

Art. II.—Of the Cortical Body or System.

§ 1.—General Considerations.

The Cortical System of Exogens is organized upon a similar plan to the Central System, but inversely as to the time of the development of the layers. It is formed of layers, each of which presents a fibrous zone internally, and a cellular one externally; and it is traversed by medullary rays, similar to those of the woody body, but less distinct. They do not differ from those of the central system, and do not deserve to detain us here; but we will now study, separately, the cortical layers in general, and the external cellular covering, which is nothing but the cellular zone of the outer layer.

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§ 2.—Of the Cortical Layers.

The bark is, as we have said, composed of layers placed upon one another, as the woody ones, but in an inverse direction. In the first year the stem is formed of a woody zone and a cortical one, and each year it forms one of each kind: the woody layer is applied upon that which was formed the preceding year; and the cortical one under that which was developed before it. Let us follow the consequences of this mode of development. The newest, youngest, and most flexible cortical layers, which represent in the bark the alburnum of the wood, are found the most internal of the cortical body. The name Liber has been given to them collectively; either because in several trees they detach themselves from one another as the leaves of a book, or because, formerly, this part of the bark of several trees was used for making paper.

The old cortical layers are thrown off towards the outside, and they have retained the name of Cortical Layers, properly so called. They represent in the bark that which the wood is in the woody body; but with this great difference,—that the woody layers, placed over one another in the order of their formation, remain perfectly entire, and are not distended in any direction; whilst the cortical layers, being placed upon each other in a contrary direction, must gradually undergo considerable distension. In fact, the first layers of bark which are developed when the stem is very small, are pushed to the outside, and distended, either by the formation of new layers, larger than they are, and situated on the inside; or by the progressive increase of the woody body. Likewise, although the number of cortical layers which are formed in the trunk since its development may be equal to that of the woody layers, they are of a very different kind: those of the bark, distended by the increase of the trunk during the first year, always present fibres more or less bent, and this disposition goes on augmenting as they advance in age; whilst, on the contrary, the fibres of wood remain usually rectilinear.

The woody layers remain in the state of alburnum, until, by the natural deposition of nutritive particles, they have acquired the hardness which they ought to have; the cortical layers, distended, and half destroyed, before this period, very soon lose their freshness, and never acquire the same degree of solidity. The former constantly preserve their thickness; the latter have a tendency to become thin by the distension and separation of their fibres. The former, protected from the influence of the atmosphere, preserve all the appearance of life; the latter, exposed to the action of the air and light, tend to dry up, to crack, and to take deeper colours: thus, the cortical layers, by the effect of their position, are first distended in such a manner, as to enclose the trunk, as it were, in a case; afterwards they split longitudinally; then they crack more or less; and whilst these phenomena are taking place, they become more or less black, or brown, externally.

The difference in position, also, gives the reason for the diversity which is remarked in the results of experiments analogous to those which we have related in speaking of the woody body. If a metallic plate, or wire, be placed between two cortical layers, the foreign body will follow the lot of the bark; it will gradually be thrown towards the outside, and will come out of the tree as of its own accord. If a nail be fixed in the bark, it will also be thrown towards the outside. If two nails be fixed at the same height, and at a known distance, it will be seen that they gradually have a tendency to separate, by the thickening of the trunk, and the distension of the fibres of the bark. If a figure, or inscription, be cut on the bark, the letters, without elongating, will become gradually thicker, larger, more separated, more superficial, and finally disappear. Inscriptions upon the bark may, then, although less exactly than those made upon the woody body, cause their date, and that of the tree, to be known. Thus Adanson, having found, in 1759, two Baobabs, upon the bark of which he observed traces of inscriptions written in the fourteenth or fifteenth century, remarked that the letters, which were six inches long, only occupied upon the trunk two feet in width; that is to say, one-eighth of the circumference; that it was, consequently, probable that they were not written whilst the tree was young. Supposing this case the least favourable of all, and neglecting the rather confused date of the fourteenth century, Adanson estimates that if these trees took two centuries in attaining six feet in diameter, they would require eight, or four times as much, to attain twenty-five feet; but as the increase of trees, as we have seen above, goes on diminishing in proportion as they become older, one cannot deduce from this observation any exact idea upon the age of these trees, which Adanson, by calculation, supposes to have amounted to several thousand years.

When traces of any ancient inscription are found upon old barks, they may serve as indications for looking for this inscription in the corresponding part of the woody body; and if it had originally penetrated the alburnum, concealed traces will be found under the woody layers: in this case, an exact verification both of the age of the inscription, and of that of the tree, is obtained. If Adanson had been able to make this research upon the Baobabs, we should have had a more certain document of the real age of these veterans of the organized world. The fact, as it has been transmitted to us, already sufficiently tends to prove the extraordinary age to which trees may attain; for, although he may have erred with regard to centuries, still this longevity very much surpasses the duration which one would suppose possible for any organized being.

Independently of the circumstances which result from their position and their mode of increase, the cortical layers differ also from the woody layers in several respects. In general they are not so thick; they have few or no tracheæ; they contain more receptacles of proper juices; in equal weights they contain more carbon; they are much less endowed with the hygroscopic property: lastly, when a plant or a branch is plunged into water, the sap does not rise into the bark.

The cortical fibres, in several plants, are remarkable for their flexibility and firmness; as is seen in those of the Hemp, Flax, several species of Nettle *(Urtica)*, several of the Malvaceæ, &c. All the fibres capable of being made into cordage, and of being spun, &c., obtained from Exogens, are the product of their bark.

§ 3.—Of the Cellular Envelope.

On the outside of the cortical layers is found a zone of cellular tissue, which bears the name of the CELLULAR ENVELOPE *(enveloppe cellulaire).* It is a kind of external pith; if it be examined in its young state, it presents, like the pith, a round regular cellular tissue, only differing from it in its position and colour. The position appears very different; but if a little more attention be paid to it, it is in reality very similar; for, in starting from the line which separates the woody from the cortical body, we see succeeding each other in regular order, the alburnum, the wood, and the pith, on one side; the liber, the cortical layers, and the cellular envelope, on the other. The colour is in accordance with its position: the pith, which is screened from the light, is white; the cellular envelope, which is evidently submitted to its action, is green. In several fleshy plants, or those with a loose tissue, as the Mistletoe, these two organs present a greater analogy; and we shall see, by-and-by, communications from one to the other. Dutrochet also confirms this analogy between the pith and cellular envelope, by showing that the pith can, in certain cases, like the cellular envelope, form, when it is laid open, a true epidermis; he designates them, in consequence, by the names of the Central Pith *(médulle centrale)* and External Pith *(médulle extérieure).*

The cellular envelope of the shoots of the same year, is green, regular, and entire; in the second year, it begins to be distended by the growth of the stem. It resists this distension more, according as the growth of the trunk is less rapid, or as the cellular envelope itself is more flexible, and, consequently, more extensible. As long as it is not too much stretched, it remains, as in most fleshy plants, in a state of greenness, freshness, and integrity; but, sooner or later, the time comes when the cellular envelope cannot suffer any more enlargement, and then it dies in consequence of the extension which it suffers. It breaks longitudinally, and thus forms the cracks of the bark; these become still deeper when the external cortical layers themselves split as their envelope. This presents, according to its texture and the mode of growth of the tree, different phenomena: sometimes, as in the Oak, or the Birch, after having been some time smooth and even, it presents irregular fissures, and is destroyed by the slow and irregular separation of its fragments; at other times, as in the Cork-tree, it presents a texture at the same time dry and flexible; from whence it results that it can live several years without falling off, and that it can, at a certain period of its existence, be taken off in considerable pieces. It naturally falls off in the Cork-tree every eight or nine years; and care is taken, a year or two before this period, to take it off for commercial purposes. For this purpose that time of the year is selected when the bark adheres most strongly to the woody body; because then, by means of proper instruments, the whole of the cellular envelope can be removed without any danger of raising the liber.

An opposite extreme to the state of the Cork-tree is the example of the Plane. Here the cellular envelope is thin, and rapidly acquires a rigid and friable consistence; whence it results that as soon as the trunk has slightly increased in diameter, the rupture and fall of the cellular envelope of the bark is caused; and this takes place every year, towards the end of summer. When a zone of the cellular envelope is detached from the tree, the external part of the cortical layer being thus denuded (which is itself found to be a zone of cellular tissue), is developed in its turn; either because it is no longer restrained in its growth, or because it is exposed to the air and light. It tends then to form again a new cellular envelope, which being of the same texture as the first, and being exposed to the same causes of alteration, lasts the same period, and is destroyed in like manner: in fact, all trees which lose their cellular envelope, lose it periodically.

There are some plants, the stems of which present very decided angles; and which, when cut transversely, present the section of the woody body perceptibly circular. The angular form is owing, in this case, to the development or peculiar form of the cellular envelope; but as the woody body enlarges and distends this envelope, the angles are effaced and the stem becomes cylindrical. It is thus that a great number of Dicotyledons, such as the Labiatæ, with square stems, &c. &c. present branches of various forms, which are all transformed, by degrees, into cylindrical stems. I know that this explanation is not applicable to all angular branches, and especially compressed ones; but it is true with regard to several.

The external surface of the cellular envelope being exposed to the action of the air and light, changes into epidermis, and presents all the phenomena which we have mentioned in speaking of that organ; but it never forms a true cuticle.

ART. III.—OF THE FORMATION OF THE BRANCHES IN EXOGENOUS STEMS.

The formation of the Branches in Exogenous Stems is sufficiently easy to understand, after the facts which we have before described.

Every leaf bears a bud* in its axil, and every bud is the rudiment of a new branch. It may happen then, and it does so in fact sometimes, that all the buds of a shoot are developed into branches; but most frequently some of them, better situated than the others, being developed first, attract all the sap; and the others being starved, as we should say, by these voracious neighbours, die of exhaustion. When this phenomenon takes place early, no trace remains of these abortive buds: this is the reason that the branches of most trees are neither so numerous, nor so regularly disposed, as the leaves. Let us abandon the abortive buds, and proceed to those which change into branches.

A bud is always placed at the summit of a fibre, and communicates, most frequently, with the medullary sheath, by the medullary rays, at the summit of which it seems situated. It communicates, however, very evidently, with the woody body; and is invested with a bark, which is a continuation of the cortical body. As soon as it begins to elongate, it presents, like the young stem, a medullary canal and a woody layer: during its growth, its base is, as it were, inserted into the woody layer upon which it originated; this is owing to the development which takes place at the same time as that of a new woody layer of the stem which bears it: the following year the young branch forms a second woody layer, and is found inserted into the trunk by a new layer which surrounds it. Thus I suppose that a branch is produced upon a stem ten years old; at the end of the eleventh year of the tree's age, the branch will have one layer, and its base will be surrounded by the eleventh layer of the stem; at the end of the twelfth

* We are here examining the branches as being the development of a bud; the structure of the bud itself, supposing a knowledge of almost all the organs of plants, cannot be described till Book iv. Chap. vii.

year it will be provided with two layers, and will be enveloped at its base by the eleventh and twelfth layers of the tree, and so on in succession. But the second layer of the branch cannot reach so low as the first, for it will find the place occupied by the eleventh layer of the tree; and for its part the twelfth layer of the stem cannot surround the base of the branch so close as the preceding, because the branch will have two layers instead of one: it necessarily results from this, that each branch, considered with regard to its base, or inserted part, presents after some years a cone, the point of which is at the place where it was originally a bud, and the base is at the surface of the trunk. This same branch, considered with regard to its projecting part, also presents a cone, the summit of which is at the end of the branch, and the base at the surface of the trunk: the longitudinal section of a stem with branches bears evidence of this structure, provided that it passes exactly to the place where a branch takes its origin. The base of a branch is, as we have seen, gradually imbedded in the trunk like a nail, by the successive development of the woody layers; but as it enlarges at the same time as the neighbouring layers, it gradually pushes them back, so as to take the form of a cone. But if a branch dies after a certain number of years, what happens? Its external cone, being exposed to the action of the air, is destroyed; but its base, which is buried in the trunk, becomes covered over with the new layers; and as it cannot any longer resist them, it is compressed and squeezed by them on all sides. This is the origin of the knots which are found in trunks; and which are so visible in planks of deal, for example. I have had occasion to see trunks of the Fir, almost all the wood of which had been destroyed by damp, except these knots, or remains of abortive branches, which, on account of their more solid texture, remained almost uninjured in the middle of the trunk. Hard-wooded trees, which have a great number of knots, or bases of abortive branches, are much sought after in the arts; either because these accidents increase their firmness, or because they produce sometimes, in sections of the trunk, various patterns, which are used for ornamental purposes.

In the preceding part of this article I have spoken of the branches which are produced from Axillary Buds; those which proceed from Terminal ones present some peculiarities which it will be convenient to point out. A bud may spring from the real summit of a branch (which takes place when the leaves are opposite, as, for example, in the Horse-chestnut); or it may become terminal by the death of the extremity of the branch (which frequently happens in trees with alternate leaves, the Birch, &c. for example); in both of these cases the new branch absolutely springs from the summit of the old one, and seems to be a continuation of it, although a slight depression is almost always visible, at least in the first year, and sometimes in the following ones.

But other combinations may also happen in cases where the stem, or one of its branches, is terminated by a bunch of flowers. After the seeds are ripe, two cases may present themselves: 1st, The axis of this bunch may be prolonged into a branch, either by a terminal bud, or because the flowers did not occupy the place; this happens naturally in the *Callistemon* and *Leptospermum* of New Holland. 2d, The axis may dry up and die, which is most frequently the case; then the buds situated below the bunch are developed: if the leaves are alternate, and far apart from one another, the uppermost bud becomes terminal; if the leaves are either opposite, verticillate, or very near one another, the stem remains as if its top were cut off, and it produces several branches at the same point: if it produce two it is said to be FORKED, or, when the phenomenon is repeated several times, DICHOTOMOUS; if three be developed, the stem is TRIFURCATED, or TRICHOTOMOUS, &c. Fig. 1, Pl. 5, is taken from a trifurcation of a branch of the Chestnut, and may give an idea of the phenomenon I have described. It may also be very well observed in the Lilac.

ART. IV.—OF THE INCREASE OF EXOGENOUS STEMS IN LENGTH AND DIAMETER.

I have already occasionally related, in speaking of the Woody and Cortical Bodies, the principal facts relative to the growth of stems; it is necessary to repeat them a a little more in detail, and to see in what point they can be referred to any theory.

Every stem, or branch, springs from a germ, at first very small, which, in developing, only dilates; so that all the parts visible after its entire development, appear to exist in miniature at the time when it was first perceived. I do not discuss here either the origin of the germs, or the general question of the formation of beings; I am only bound to express a fact, such as observation gives it.

The part which may be considered as the development of a germ, elongates to a certain limit, determined by the necessary time for the fibres to acquire the degree of firmness peculiar to their nature: stems or branches usually acquire this at the end of the first year of their life. When marks are placed at equal distances from one another, upon a growing stem or branch, we see, when its increase in length stops, that the marks are all separated from one another, but all remain at perceptibly equal distances; whence Duhamel, to whom this experiment is due, concluded that the elongation took place throughout the whole length at once, during the first year. One would have arrived at the same results from the simple observation of natural facts: all the leaves already exist upon the growing branch, but very near one another. In following their development we see, it is true, that the elongation of the branch commences at the base; but when it stops growing, the leaves are much more distant from each other than they were before, but at nearly equal distances; sometimes those of the higher end are nearer each other, probably on account of the incomplete development of the branch. The observation of the Lenticels, Glands, Hairs, or Stings, which may be found regularly disposed upon the branches, leads to the same results. We may, then, regard it as certain, that stems or branches, during the first year, elongate nearly equally throughout their whole length, if we consider them together; but when we examine the increase of this branch in part, we see, with Cassini, that each merithallus, or internode, grows principally by its lower part; or, in other terms, that its superior part is formed before the lower, the extension of which produces the increase in length: thus it is easy to see in the merithalli of *Ephedra*, or of the Caryophylleæ, that the lower part is softer and younger than the upper. The same law is found in grasses: perhaps it is common to all stems, and is essentially owing to the nutritive action of the leaf upon the merithallus which bears it.

After this first period, a branch or stem grows no more, and the plant only elongates by the addition of a new shoot, which springs from its apex, and which ought to be considered as the development of a new germ. Let us first follow the case where the germ is situated exactly at the summit; it is developed during a year, following the same laws as that of which it seems the continuation. The stem is found elongated by a body perfectly similar to that of the preceding year; and thus it goes on successively for an indefinite period. A young shoot, formed of the organs above described, acquires, during its first year, a certain thickness, determined by the thickness of the woody and cortical cones: the second year, at the same time that a new shoot springs from its summit, it forms in that of the preceding year a new woody zone, which is placed on the outside of the old one, and a new cortical one, situated within the preceding one: these two zones then are developed in the space situated between the cortical and woody bodies. What is their origin? Such is the delicate question which has occupied the greater number of anatomists and physiologists; for it appertains to both these sciences. What we shall say with regard to the increase in diameter of the stems of Dicotyledons, is equally true with respect to their roots.

Du Petit-Thouars, impressed with what takes place in the formation of the branches of *Dracœna*, (which we shall speak of under Endogenous Stems,) applying, by analogy, his observation to all stems, and partaking of the idea, which appears to us very just, that the liber does not change into alburnum, has proposed an opinion, as bold as it is ingenious, upon the origin of the woody fibres; viz. that they are the prolongation from above, downwards, of the buds or germs which are developed. Thus, if we revert to what I have said of the elongation of stems by the formation of a new shoot at their extremities, he supposes that, at the same time that this new shoot is developed, the fibres which are found there are prolonged downwards; and form by their union a woody sheath, which creeps down between the wood and bark of the lower part of the tree, and thus forms a new woody layer, placed over the former one. A bud or germ which is developed on a tree, does not essentially differ, according to him, from an ordinary seed: the young shoot which springs up represents the plumule; the pith plays the part of the cotyledon; and the woody fibres are the roots of the bud. These roots have a tendency to descend, as those of the plant itself; and, in descending, they insinuate themselves into the only passage which they find permeable.

Numerous objections have been made against this theory. 1st, It is said that these roots of the buds ought to be seen, at some period of the life of trees, descending all along the woody body, as is said to be the case in *Dracæna*. Du Petit-Thouars has been obliged, in order to answer this objection, to suppose that this descent takes place with such rapidity as to escape our notice; he even goes so far as to compare it to the swiftness of the electric spark, or of light. 2d, It is remarked that in grafted trees the wood situated below the graft resembles that of the stock, and that above it is like that of the graft: thus, when an Almond, the wood of which is yellow, is grafted on a Plum, which has the wood red, the wood is red below the graft, and yellow above it: now it seems evident that if the wood were formed by the buds, it ought, from the top to the bottom, at least externally, to resemble that of the graft. Du Petit-Thouars answers, that the woody fibre which descends from the bud retains the nature of the graft; whilst passing under its liber it is nourished by its juice, but when it arrives under the liber of the stock, this furnishes it with another nourishment, which changes its nature. 3d, It is asked, in this theory, how the cortical layers, which appear to be produced at the same time as the woody layers, are formed? But it might be answered, that they have the same origin as the woody layers, and are thus derived from the buds. 4th. It is observed, that if the buds of a branch of the Plane-tree, or Willow, be removed, and it be then placed in water, it shoots out roots from the lenticels before the visible development of new buds; and it has thence been concluded that the origin of roots has no connexion with that of the buds. Du Petit-Thouars thinks to answer this objection by remarking that there exist latent or adventitious buds, which begin to be developed, and cause the production of roots. 5th. An experiment, which appears to me decisive upon this subject, is this:—If a circular notch, or an annular section, be made in the bark of a tree, in such a manner as to cut off all communication between the upper and lower parts, it is clear that, at the end of a year, if it be the buds which produce the woody fibres, it will have one layer more above the section than below it, and this layer will be formed of descending or longitudinal fibres: that if, on the contrary, there only descends from the upper part of the tree the nourishment elaborated by the leaves, there will be the same number of layers above and below the section; but the layer of the upper part, being more nourished, will be the thicker, and that of the lower will be smaller and thinner. But the experiment* has given this last result in Exogenous trees; and one is compelled, it seems to me, to conclude, that the woody layers are produced by the formation of fibres which do not proceed

* This experiment has not perhaps been made with all the care that could be wished; and as it appears decisive for or against the theory, it is desirable that it should be repeated.

from the buds. I do not deny, however, that the buds, or rather the leaves which they produce, have some influence upon the formation of the wood; but it is an action which appears to me to be purely physiological; they elaborate the descending sap; and we know from this that the more buds or leaves there are in the upper part of the tree, the more the young wood is nourished. Thus, whilst Du Petit-Thouars attributes to the buds the origin of the fibres, and to the alburnum and liber their nutrition, I am of opinion that the leaves produce the nourishment, and that the fibres are developed by the liber and alburnum.

Turpin has modified the opinion of Du Petit-Thouars, in admitting two classes of fibres; one of which descends from the aerial buds towards the roots; whilst the others arise from the extremities of the roots, and go in a contrary direction to the preceding. He thinks that each of these two systems of fibres is prolonged as long as the contrary one does not meet with any obstacle: this explains, according to him, how, in the case of the dissimilar graft, of which I have lately spoken, the lower part of the trunk remains of the same nature as it originally was; but in this theory we cannot understand either how the roots can give nourishment to the ascending fibres, the existence of which is not demonstrated; or how these fibres, which are supposed to spring from the roots, can take a nature and properties so different in passing the neck.

All other naturalists, although there is little accordance between them, are agreed at least upon this point,—that the formation of the new woody and cortical layers is produced at the point of contact of the two systems, and ought to be considered in the horizontal, and not in the vertical direction. A very simple fact demonstrates this proposition: If a tree, which has been grafted upon another, be cut longitudinally at a given height, it is found that from the heart to the circumference, the wood and the bark are both of them, below the graft, of the same nature as the stock; and that above it they are of the nature of the graft. Three opinions have been put forth to explain this fundamental fact:—either the alburnum produces the bark,—or the bark the alburnum,—or the alburnum and bark each produce a layer of their own nature. The first opinion has been supported only by Hales, and is without very striking proofs. It is easily opposed by the extreme difficulty that all plants present to live and grow when deprived of their bark; and by the collection of facts.

The opinion that the alburnum is produced by the bark, is subdivided into two. Some, at the head of whom is Malpighi, thought that the internal layer of the liber changes into alburnum; others, after the example of Grew, believed that the liber produces the alburnum, but does not change into it. Without absolutely deciding between Malpighi and Grew, Duhamel has remarked, that if a plate of silver be placed between the woody and cortical bodies, it is found, after some time, covered by new woody layers; whence he concludes that their formation is due to the bark, and is produced by means of the mucilaginous substance which is found between them, and which he calls CAMBIUM. This experiment, which seems conclusive, still leaves some points in doubt; viz. 1st, The difficulty of being assured that the plate of silver has been really placed between the wood and the bark; and 2d, The possibility that the cambium may be produced by the wood, and that it may be sufficiently fluid, in its first state, to flow over the plate of silver, and to cover it over on the outside, although originally proceeding from the interior. Duhamel, who perceived these reasons for doubting, has not ventured to draw any direct conclusions. Mirbel, who repeated his experiment, concluded, first, that the liber changes into alburnum; he has since only said that the liber divides itself between the wood and the bark. Knight, Mustel, Du Petit-Thouars, Dutrochet, &c. have, on the contrary, maintained that the liber does not change into alburnum; and this opinion has always appeared to me most conformable to the generality of facts. Kieser arrives at the same conclusion, in consideration of the difference of the tissues of the liber and alburnum.

The third opinion, which tends to establish that the alburnum forms the woody layers, and that the liber produces the cortical ones, has been maintained, first by Mustel, and since by Dutrochet. The former is contented with denouncing the opinion, that the ascending sap of the woody body forms a kind of liber, which is converted into alburnum; and that the sap descending by the bark forms a kind of cortical liber, which is converted into true bark. It is founded partly upon an inaccurate observation; viz. that the woody layers are formed in the interior of the medullary canal; whence it is concluded that they may be as well formed upon the outside of the woody body. The inaccuracy of the opinion of Mustel, as to the function of the two saps, appears to me to be sufficiently demonstrated by an often repeated observation, that the woody layers which are formed are thicker in proportion as the access of the descending sap is more easy. Dutrochet has given more precision in his researches in this respect; he has made them chiefly upon herbaceous Dicotyledons, seeing that the compact and close tissue of woody plants renders them, according to him, more difficult to be observed. He was the first to remark, that under the name of the increase of trunks in *diameter,* we connect, in reality, two distinct phenomena—viz. the increase or extension of layers already existing, which he calls their increase in width *(largeur),* and the addition of new layers, which he calls their increase in thickness, *(épaisseur.)* The increase in diameter may result sometimes from the union of these two phenomena, and sometimes from the existence of only one.

According to this observer, the extension of layers already existing takes place, both in the cortical system and in the central one, by an analogous process; and that, as regards the bark, it can easily be followed in autumn in the root of *Echium vulgare;* and as to the woody body, in spring, in the young shoots of *Clematis Vitalba.* In both, on cutting them at different heights, in order to have the comparison of different ages, we see that the horizontal section of a layer presents a certain number of fibrous bundles, separated by vertical plates of cellular tissue—the medullary rays; that these rays are, at certain periods, divided into two plates by a row of fibres which are developed in the middle, and, gradually separating them, begin by forming kinds of festoons, and afterwards two distinct medullary rays; and that, lastly, these bundles of longitudinal fibres develope in their middle new medullary rays. This formation explains how there are many more medullary rays in the layers on the border of the woody body than in those of the centre,—as can be easily seen in the section of the branches of *Quercus toza,* (pl. 5, fig. 3.) Analogous phenomena take place in the bark and woody body, and cause us to understand the increase which the already existing layers take. The formation of the medullary rays, the primitive and secondary ones of the woody body, is in accordance with the angles of the medullary canal; and that of the cortical rays is with the little channels visible on the outside of several barks. This increase in length of the layers tends to explain several cavities, or intervals, which are formed in the medullary cavities of Dicotyledons; for example, in the Sunflower *(Helianthus)*, a great number of the Chicoraceæ, &c.

The formation of the new layers, both woody and cortical, is, in following the observations of Dutrochet, a phenomenon different from the preceding. A layer of alburnum and one of bark, simply in juxta-position, are formed at the same time, which at first present the appearance of a simple jelly; but this is not a simple deposited juice, but a substance already presenting traces of organization and the appearance of a young tissue. The existence of this young layer is very easily recognised, on examining, in spring, the roots of *Dipsacus Fullonum, Eryngium campestre*, &c. Each of these layers distinctly presents a cellular zone, (which represents the pith,) and a fibrous one. The cellular zones of each layer are developed the first in spring, and then they are contiguous; soon the two fibrous zones, the one woolly and the other cortical, are developed between them; and thus it takes place each year. This development of new layers, which Dutrochet names the increase in thickness, takes place during the whole life of the plants; that in width continues indefinitely in the bark of trees, which always retains a certain softness; but it is early arrested in the solid parts. Herbaceous plants, as Sunflowers, increase in breadth as long as they live, and this causes those cavities of which we have spoken. Dutrochet doubts that the addition of new layers takes place universally among Dicotyledons; founding his opinion upon this—that these layers are not distinct in some long-lived roots, such as the Chicory *(Chicorium Intybus)*, &c.; but it is more probable that this apparent exception only results from the fibrous zones of the layers being separated by very narrow medullary ones.

Section III.

Of the Stem of Endogens.

Art. I.—Of the Stem in general.

The Stems of Endogens, considered in general, have the following characters in common:—1st, They are never composed of two bodies which increase in a contrary direction with regard to each other, but present a single homogeneous mass;—2d, They never have a true medullary canal, or distinct medullary rays;—3d, They have the oldest fibres, or layers, at the circumference, and the newest in the centre. It is from this last character that I have given them the name by which I call them, and which indicates that they increase by additions to the interior. These characters are less complicated, and a little more vague, than those of Exogens; the stems of Endogens, also, present less regularity than those of Exogens. In order to avoid confusion, we shall be obliged to describe them separately.

It is, without doubt, this diversity in their form which has for so long a time prevented their general characters from being known. We find in the writings of Grew, Malpighi, and especially in the *Mémoire* of Daubenton upon the Organization of Wood—we find, I say, in these authors, exact, but scattered and inconsistent observations, upon the differences which the stems of Endogens present. Linnæus seems to have perceived them, by giving to some of them the particular names of *Truncus, Stipes, Caudex, Culmus;* but it is to Desfontaines that the science is truly indebted for the first general and exact ideas which it has acquired upon this important subject; he was the first, in his *Mémoire* upon the Comparative Structure of the Trunks of Monocotyledons and Dicotyledons, who laid hold of the essential characters of the general structure of Endogens, and by this good observation opened to anatomists an entirely new path. Mirbel and Du Petit-Thouars have also published some interesting observations upon the structure of the different families of this class, and upon their growth.

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§ 1.—The Stems of Palms.

The stems of Palms are, of all Endogens, those which have excited most attention by their slender form, and the singularity of their appearance: they have been more carefully studied than the others; and, in giving a detailed description, we will dispense with many repetitions in the following Articles.

The stem of Palms is usually erect, strong, simple, regularly cylindrical, and crowned at the summit with a tuft of leaves, the number of which is nearly constant. If it be cut transversely, we see that it is only composed of scattered fibres, intermixed with a cellular tissue, which connects them with one another. We also remark at first sight, that the fibres of the circumference are close to each other, of a very firm texture, and evidently older than the inner ones; these, on the contrary, are separate, soft, of a more herbaceous nature, and surrounded by a loose and feculent cellular tissue. Each fibre is a bundle of tracheæ and striped and dotted vessels, intermixed with elongated, and surrounded by round cellular tissue. The difference in texture between the circumference and centre of the trunk is always perceptible — sometimes very remarkably so; there are some Palms, the outer part of which is so hard that the axe can make no impression on them, whilst the centre is a loose and spongy tissue, which is readily affected by moisture. The circumference of Palms represents, as to consistence and age, the wood of our trees, whilst the centre is a kind of alburnum. But these two organs are placed inversely to that which we are in the habit of seeing in Exogens: it is from this central alburnum that the leaves and flowers spring; it is, in a word, always from the centre that the development of all parts of Palms commences. The young leaves of the annual shoots of Exogens also spring from within the older ones, or from the interior of the buds; but if in this respect the two great classes resemble each other, as Dutrochet has remarked, they do not differ less in this, that all the rest of the development of the trunk of Exogens is made by the addition of new woody layers outside the first; whilst in Endogens, the increase takes place by the interposition of new fibres, principally towards the centre of the trunk.

At the first development of the plant, the first row of leaves is connected with the neck by a layer of fibres; in the second year, there springs from the interior of this first row a second row of leaves, which have also a layer of fibres placed within the preceding, which, by their development, help to distend the first layer. It is the same with all the following layers, until the period when the external one, having acquired by age the hardness of perfect wood, can no longer be distended by the fibres of the interior; then the first-formed zone hardens, and cannot increase more in diameter the following year; and, by the same causes, the second zone hardens, and forms a ring above the first: this takes place in all the following years, so that the stem is strictly cylindrical, its external part being composed of perfect wood, and its interior of fibres not as yet hardened.

A rude image of this evolution of the Palms can be made by comparing them to the parts of a telescope, which can be disjointed from one another; also by likening it to the bark of an Exogen, which grows independently of the woody body;* but in these comparisons, and also in my description, I have been obliged, in order to make myself understood, to speak of layers; and these layers, although they might appear really to exist, are not always distinct enough to be perceived. We see, then, from this description, that if we were able to count the layers or the fibres of the transverse section of a Palm, the solidified layers would be, throughout the whole length of the tree, in proportion to the age, and the rings would present the number of years the tree had lived; but it is impossible to distinguish them. We may know the age of Palms in a very simple manner—viz. by counting the rings, which are often marked externally on the trunk, and which are the cicatrices of the leaves; but these may imperceptibly disappear, so as not to be able to be counted in old trees. As the annual elongation

* M. Lestiboudois has followed this metaphor, and considered it as a reality; but he has not borne in mind that the trunk of Palms can by no means be compared to the bark of Exogens, since the ascending sap constantly rises by the trunk, whilst it never does so by the bark. This well-known fact is sufficient to prove that this trunk is more analogous to the woody than to the cortical body of our trees. The difference between these two classes of bodies is confirmed by anatomy; for the trunk of Palms presents tracheæ, and striped and dotted vessels, like the woody bodies of Exogens.

is regular in each species, the total length is sufficient to give a pretty exact idea of the age of the individual.

Is the stem of Palms, as Linnæus has thought, and as the stems of the Plantains would seem to demonstrate, any thing more than the bundle of the petioles of the existing leaves sheathed by the hardened and persistent ones of the old leaves? It is in this point of view that the name of FRONS, which signifies a leaf, or STIPES, which means a support, has been given to it. This hypothesis might be applicable, if one considered it as a metaphor, but it can be but little followed as the expression of the reality.

The stem of Palms is, as I have explained, a cylinder, which grows indefinitely in height by its extremity, and the thickness of which is determined in each species by the time necessary to solidify a layer after the first period of its development. It sometimes happens that the trunk presents here and there transverse contractions, or swellings. These anomalies are owing to the tree having had, at those periods, a slower or more vigorous growth. There is in one of the greenhouses of the Jardin-des-Plantes at Paris, a Cycas (a tree analogous to the Palms in the structure of its stem) which has, in the middle of its length, a very distinct contraction, which corresponds to the period when it was being brought from the Isle of France to Paris. During this transportation it received but little nourishment, and the solidifying of the external fibres took place before they had attained their full size. Similar contractions can never take place in Exogens; and, on the other hand, Palms, and other Endogens, can never present lateral exostoses, since all their fibres are longitudinal; and the external ones, already hardened, form a kind of sheath around the younger ones.

We have seen above that when Exogenous trees are surrounded by cord or wire, they have a contraction in that part on account of their increase in diameter. It is evident, that since the diameter of Palms only increases in their young state, they are protected from this accident during the rest of their lives: this explains a phenomenon which I have witnessed, of a Palm which has become surrounded at a great height by a *Bauhinia*, the branches of which, in uniting together, enclosed it in an irregular interrupted sheath, without having altered the cylindrical form of the trunk.

All this assemblage of rectilinear fibres, of which I have spoken, is surrounded by a zone of cellular tissue, which may be compared to the cellular envelope of Exogens; but it however presents remarkable differences:—1. Nothing representing the cortical layers is found beneath this envelope; 2. Under it, at least in the Palms with simple stems, no woody layer exists: and it is very doubtful whether it be formed even in the small number of Palms which are branched. 3. This envelope not being distended beyond a certain limit by the increase of the trunk, preserves for a much longer time its thickness and form; it is usually thin, and cannot at any period, in the Palms, be separated from the trunk, and no trace of medullary rays is ever found in it more than in the trunk.

If the growth of the stems of Palms be compared with that of Exogens, we see—1. That the increase in length is produced in the two cases by the formation and the development of a terminal bud, which lengthens the already existing trunk;—2. That the increase in diameter can take place until a fixed age in each species, either by the dilation of each bundle of fibres by means of fibrous or cellular tissue, which is interposed; or by the development of new bundles towards the centre of the tree.

That which we have said of the stem of Palms is applicable, with very slight modifications, to those of the Cycadeæ, the Asparagi which do not branch, arborescent Liliaceæ, &c. The small number of Palms which, like the *Calami*, have the stem knotted, entirely approach the culms of Grasses; and when speaking of these we shall notice it.

The stems of Palms are almost always simple, and without ramifications; in some species, however, are found branches, either accidentally, as in some Dates, or regularly, as in *Cucifera Thebaica*, Delile, *Hyphæne coriacea*, Gærtner; which is constantly divided into branches several times bifurcated. The mode of ramification of Palms has not as yet been studied carefully, and it merits the attention of observers resident in the countries where they grow. From the little that I have seen in other trees, I am inclined to believe, with Du Petit-Thouars, that all the leaves of Monocotyledons have in their axil a vital point or latent bud, like Dicotyledons; and that this bud is only developed when the growth of the upper part of the stem presents some obstacle to the passage of the sap, and makes it consequently flow back in greater quantity.

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§ 2.—The Stem of the Liliaceæ, Asphodeleæ, Pandaneæ, &c.

I use here, in order to be concise, the term Liliaceæ in the very wide sense which Tournefort gave to it; the stem of these plants, when it is simple—as, for example, in *Yucca* and *Dracæna umbraculifera*, differs very little from that of Palms, both as to its form and its development. It is in the same manner cylindrical, and surrounded either by the remains of the leaves, or by a cellular zone; it is composed of bundles of fibres, which are more compact towards the circumference, and looser in the centre of the stem; and always surrounded by a cellular tissue, which seems to replace the pith. It does not increase in diameter after a certain given period. But Liliaceæ with branching stems present singular phenomena: some, such as the Asparagi, properly so called, although very branching, do not increase in diameter after their first development; others, such as *Dracœna Draco*, grow very much at the same time that they branch. Du Petit-Thouars has observed that when the *Dracœna* shoots forth branches, each of them at its first development produces fibres, which are interposed, he says, between the cellular zone and the woody body;—that of these fibres, those which are inferior have a tendency to descend, and those which are directed to the upper side quickly bend and descend as the preceding; whence he concludes that the descending fibres of these buds cause the increase in diameter of the trunk. This very remarkable fact unfortunately cannot easily be studied by European botanists, and as yet remains unseen by us, especially if it be considered that the branching Asparagi of our climate do not present any resemblance to them.

The ramifications of the Pandaneæ have much affinity with those of the Asparagi. I have before me a trunk of *Pandanus*, in which is seen the origin of a branch. It presents, as is usual in Endogens, a mass of longitudinal fibres: the base of the branch, cut transversely, has also the same appearance; but the union of the two bodies appears to take place, because the fibres of the branch penetrate perpendicularly into the trunk without anastomosing with the longitudinal ones, but cutting them at right angles, so as to form a kind of netted cross. I have said, in order to follow Du Petit-Thouars's idea, that the fibres of the branch penetrate the trunk; perhaps I should have done better in saying that certain fibres of the trunk passed through the vertical bundles, and penetrated the branch.

This suspicion seems authorized by the examination of the trunk of *Xanthorhœa hastilis.* I possess a piece of this singular plant, discovered in New Holland by M. Gaudichaud. At the first view of a vertical section of it, one would completely take it for a Dicotyledon, and in fact I at first feared that there had been some mistake about it; but, on the one hand, Gaudichaud, whose accuracy is well known, distinctly remembered the origin of this specimen; and, on the other hand, on examining it, an organization is perceived, which, if it be not similar to the usual state of Monocotyledons, differs still more from that of Dicotyledons. This piece presents a very thick and wrinkled cellular zone, perfectly resembling that of an Exogen; the woody body is formed, 1st, of vertical fibres, rather loose, and very like those of Palms, or of *Yucca;* 2d, of other fibres, which, radiating from the centre, pass through all the preceding, cutting them at nearly right angles, and are prolonged even through the cellular zone, under the form of fine lines: these horizontal fibres resemble medullary rays in their position, but differ from them in their nature; they are not vertical plates, but fibres, joined two or three together. Do these fibres, which spring from the central part—are directed towards the foliaceous organs—and thus remain, as it were, inserted into the trunk—serve for the origin of the leaves? This suspicion would seem to be authorized by considering that the leaves of *Xanthorhœa* are very numerous, and disposed not only upon the summit but throughout the length of the branches. All the cortical part, and the trunk of this tree, are impregnated with a reddish brown matter, which appears to be the true Dragon's Blood, analogous to that which is extracted from *Dracæna Draco*.

The stem of the Liliaceæ, which, considered in *Dracæna* and *Yucca*, hardly differs from that of the Palms, and is elevated to the height of a tree or shrub, presents in other species an entirely different appearance: thus, the stem of *Aloe*, of *Anthericum frutescens*, &c. is of a woody texture, but attains a less size than the preceding, forming little shrubs or under-shubs. In the Smilaceæ, Dioscoreæ, and several Asparagi, the stem is very long, but slender, and more or less twining, without differing however from the preceding, more than the climbing Convolvuli do from the shrubby ones: in others—as, for example, the Lily, Fritillary, Pine-Apple, &c., the stem remains herbaceous, cylindrical, long, upright, firm; and does not differ from the woody stems which we have mentioned, except in its texture, that is to say, just as the herbaceous Leguminosæ differ from the trees of the same family. In all these cases the stem is a distinct organ, and, when it is perennial, is terminated by a single bud, which is larger in proportion as the stem is less branched. But in some species which are called bulbous, the stem is very short, being reduced to an orbicular plate concealed underground, and surrounded by the persistent scales of the terminal bud; this we see in the Tulip, Hyacinth, Garlic, &c. We find all the intermediate degrees of length between the arborescent stems mentioned just now, and the subterranean ones of bulbs; thus, among the species of *Crinum*, some have the stem elongated, and rising above the ground a foot or more in height; and there are others with it short and buried in the earth; in the genus *Allium*, most of the species of which have the plate of the bulb short and scarcely perceptible, there are some in which it takes the appearance of a true stem, although it remains underground, as *Allium senescens.* This last mode of development of the stem is frequent in *Iris, Amomum, Acorus,* &c.; and this organ then receives the name of RHIZOMA, to indicate that it resembles a root, because it is subterranean; but it is a true stem, which remains buried underground, producing true roots, and from its apex leaves and annual shoots: these bear the flowers, and frequently leaves; they are like the annual stems of perennial Dicotyledons, whilst the Rhizoma represents the persistent stock, which, in the Asters and Pœonies, &c. remains beneath or on a level with the surface of the ground, and produces each year new floral shoots. Although I have mentioned these facts in speaking of stems in general, I have thought it right to return to them here, both in order to show that the same principles apply to all the stems of the Liliaceæ, however different their forms may be, and to serve as an introduction to the following Article.

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§ 3.—The Stem of the Bananas.

It is usual to describe, under the name of the Stem of the Bananas, the cylindrical body which bears the leaves, and is terminated by the cluster of flowers; and under the name of the Root is confounded all the subterranean parts; but when we examine these organs, and are guided by analogy, we readily perceive—1st, that the subterranean part is composed of true roots, and of a persistent rhizoma; 2d, that the elevated portion, which perishes after each time of flowering, is a kind of false stem, formed by the sheaths of the leaves which surround the scape or floral peduncle, and are united to it. These sheaths are, thus to speak, the petioles of the leaves; and they can be separated from each other, so that their true nature can be very readily recognised. They form nearly cylindrical tubes, inserted into one another, the transverse section of which is seen when this floral stem is cut horizontally. An analogous organization appears to exist in most of the Scitamineæ, although in a less evident manner; and it is perhaps the same in several other Endogens, when one equally distinguishes a persistent part, (which is the true stem, whatever may be its situation,) and a floral part of limited duration. The distinction between the true stem, and the organs formed by the peduncles and the bases of the leaves, is, in certain genera of this class, very difficult to be fixed with precision.

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§ 4.—The Stem of the Gramineæ.

Botanists have usually called the stem of the Gramineæ, or Grasses, by the particular name of the CULM *(culmus; chaume)*; and it deserved in fact a peculiar name in the old system of the nomenclature of organs, where there was a tendency to designate all their modifications by proper names: the immense number of these modifications gradually caused this method to be abandoned, because it presented the great inconvenience of concealing under different names the real analogies of organs.

The Culm differs from other Endogenous stems in this:—that at the origin of each leaf is found a knot or plexus of very numerous and compact fibres; in every part of the stem between the knots, or in the internodes, the fibres are parallel, vertical, and do not deviate under any circumstances; there are never produced, in this interval, either leaves, branches, or roots: on the contrary, in the knots, the central cavity occupied by the cellular tissue is interrupted, the fibres cross in the horizontal direction; they give rise to a sheathing leaf, and in the axil of this is always found a bud, which is developed or not according to circumstances. It is from this knot also that all the adventitious roots spring in grasses, when their stems or lower branches are either prostrate or subterranean—as, for example, in *Triticum repens* and *Panicum Dactylon*, where the lower branches are prolonged horizontally underground, and commonly bear the name of roots. Frequently, also, in grasses with upright stems, the lower knots are so near the ground that it often happens that they shoot forth roots.

The distance between the knots is very variable, not only in different grasses compared together, but also in individuals of the same species, and in the knots of the same individuals: in general they are more distant when the stems grow in a fertile soil, and upon the same stem they are seen nearer together at the base, and more separated above. We also remark, that the closer the knots are, the more easily is the axillary bud of their leaf developed; this takes place in the grasses which ramify principally at the báse of the stem.

When the lower internodes are very short, it often happens that they swell up so as to form a kind of dilatation, which, covered over by the sheath of the leaf which it has distended, resembles the bulbs of the Liliaceæ: this has caused some of the Gramineæ to be called bulbous; such is, for example, *Hordeum strictum*, which is often bulbous, and then it receives the name of *H. bulbosum; Phleum nodosum* probably only differs from *P. pratense* by this same phenomenon taking place.

It sometimes happens that the swollen knots are separated by a short internode, and then the series of these tumified knots gives a singular appearance to the subterranean part of the stem. A variety of the Wild Oat *(Avena elatior)*, which has been called *A. precatoria*, or Necklace-like Oat, presents this structure. The knots situated above the earth are never swollen in a remarkable manner except by accident.

The internodes are covered in the lower part, or throughout the whole of their length, by the sheaths of the leaves: this covered part is always softer and more herbaceous than the part exposed to the air; it never presents any hairs, and rarely stomata so well developed as those of the exposed part.

The interior and central part of the whole length of the internode is always softer than the exterior, and only presents a dilated cellular tissue, which, in its young state, is filled with watery juice, drying up as it grows older; sometimes it remains entire; at other times it is more or less completely broken, forming the hollow Culms, or those cavities in reeds which run from one knot to another.

All that we have said of the Gramineæ is applicable to the *Calami*, which belong to the family of the Palms, but have their stems marked here and there with knots which bear the leaves and give birth to axillary buds.

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§ 5.—Of the Stem of the Equisetums.

The stems of the Equisetums have much analogy with those of the Gramineæ, but they seem, at first sight, to approach a little more to those of Exogens; they are cylindrical, furnished with solid knots, from which spring the verticels of branches and leaves. The internode presents, in its interior, a central cellular tissue, which is very early broken, so as to form a hollow cylinder, composed of two rows of fibres, an external and an internal one, disposed so as to alternate with each other: seen through the microscope, they are composed of striped vessels intermixed with dotted ones, and elongated cellules; the external ring presents tubular air-cavities, disposed with great regularity.

In the knots the central cellular tissue is not broken, and seems to enjoy the function of pith: from the external border of it, or from the internal part of the external cylinder, there proceed striped vessels, in a horizontal direction, which go to the surface, and are there developed into branches which are organized as the stem.

All the parts of the Equisetums which we have been accustomed to call stems, are annual, and spring from a rhizoma, or subterranean stock, the organization of which deserves a very attentive examination, because it appears capable of attaining an extremely advanced age, and might, consequently, give us some idea of the mode of growth of Endogens.

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§ 6.—Of the Stem of Ferns.

The stem of Ferns presents itself under three very distinct appearances: sometimes it is erect, firm, cylindrical, and simple, as that of Palms; this we see in *Cyathea spinosa, Dicksonia*, &c.: sometimes it is weak, climbing, twining around trees, branching, but manifestly cylindrical in each ramification—as, for example, in *Ugena*, &c. There are some which have it creeping upon the ground, as in *Polypodium Virginicum.* Finally, in the small Ferns peculiar to our climates, the stem creeps along under the surface of the ground instead of above it, and presents itself under the appearance of a subterranean nearly horizontal stock, which emits roots from its lower side, and leaves from its superior extremity; it is gradually destroyed at its older end, whilst it lengthens by the opposite extremity. One can no more refuse to recognise the identity of this subterranean stock with the aerial stem of the Tree Ferns, than in similar cases in the Liliaceæ and other well known families.

The stems of Ferns, whatever be their direction, are always cylindrical, and harder towards the circumference than at the centre. They are eminently distinguished by this—that when they are cut transversely, we always observe in them brown spots, round and symmetrical, but of various forms: it is these which, when seen in an oblique section of *Pteris aquilina*, have been compared to the figure of a German eagle. These spots are formed, according to Mirbel, by the transudation into the cellules of the most spongy part of the stem, of a juice secreted by certain fibres. From an examination of them in the Tree Ferns, we are obliged to consider them as bundles of very compact fibres, which are separated by spaces essentially full of cellular tissue. The central part is sometimes hollow in aged stems, by the destruction of the cellular tissue. The stem, cut transversely, presents an external ring of cellular tissue, which performs the part of bark as to its position, but does not influence the formation of the wood, which is developed by the interior of the central fibrous cylinder: this cylinder presents a great number of striped vessels; the ramifications of the stem spring entirely from it, and they do not seem to be any thing but the results of the divergence of the fibres.

Every part of the surface of the stem appears endowed with the faculty of producing roots; this we see very clearly in the rhizomata or subterraneous stems of the Ferns of our climates. I have in my possession the lower part of a Tree Fern, which M. Perrottet has had the kindness to send to me from Martinique; it is covered for about three feet above the neck, with a thick and compact plexus, formed of an immense number of little fibrous dry brown roots, which are situated all around the trunk, forming a kind of covering for it; these roots have, themselves, surrounded in their growth the climbing stems of *Caladium*, which, seen in the adult state, appear to have perforated this radical tissue.

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§ 7.—The Stem of the Lycopodiums.

We observe in the Lycopodiums two distinct but continuous parts; on the exterior is a kind of envelope of round cellular tissue; in the centre is found a small cylindrical column, composed of striped and dotted vessels, surrounded by elongated cellules; and the branches are formed of little bundles, which separate from the central cylinder, and where the cellular tissue is developed on the exterior, according as it is found free from the pressure of the neighbouring fibres. This cellular envelope of the Lycopodiums, and of several other Endogens, has only a general resemblance to that of the bark of Exogens, but there is nothing in it like the cortical layers or the liber.

The *Isoëtes* is a kind of Lycopodiaceous plant of inundated places. Its stem, instead of being elongated and filiform, as in the other genera of the family, is thick, oval, slightly triangular, and has the appearance of a tubercule: this stock presents a bundle of primitive roots, which spring from the base; and three lateral bundles, which are developed as adventitious roots in three longitudinal furrows. That which appears most singular in its history is, that from time to time, (at periods which I have not been able to determine, but I believe each year,) three disks are detached and thrown off from the three round sides of the stem. These oval disks bear upon their sides the remains of roots, which were the most external of each of the bundles of adventitious roots. I have not been able to discover any vessels in this opaque, compact, and almost farinaceous mass of the stem or stock of the *Isoëtes;* but I am inclined to believe that they exist, since the leaves are furnished with stomata.

Art. II.—Of the Formation of the Branches in Endogenous Stems.

From what we have seen in the preceding Article, it is clear that the structure of Endogens appears less uniform than that of Exogens; and that which relates to their ramifications, presents, in particular, much diversity. The real number of these irregularities also seems increased by this circumstance, that the number of woody Endogens with which we are accurately acquainted is very inconsiderable, and that we have very frequently neglected the intermediate forms which might have been able to give us an explanation.

If in this as yet imperfect state of the science, we endeavour to give an account of the ramifications of Endogens, we shall find great difficulties. It appears to me very likely that in the axil of each leaf there exists, as in Exogens, a vital point, or latent bud; and that this rudiment can be developed, or not, according to circumstances. When the leaves are placed upon a knot, or plexus of vessels, which arrests the progress of the sap, and also often presents a deposit of nourishment, then the bud is frequently developed into a branch; this is what happens in Grasses, *Calamus*, and *Equisetum*. But when the stem does not present a natural knot, there are accidental causes which make it branch. I shall point out some of them.

If the top of the stem of an Endogen be cut off, the buds which are found in the axils of the upper leaves receive the sap which naturally would have been employed in the elongation and nutrition of the central and terminal portion; these buds grow and form branches: if one of them be better situated than the others for its development, it alone elongates, and the stem seems to remain simple, although it is really branched; if two or more of these buds are equally developed, the stem is bifurcated. Such are the facts of which there is evidence in our botanic gardens, when it is desired to multiply Endogens, or to make them branch: thus, when the top of a stem of *Yucca, Littœa*, or of every other analogous plant is cut off, it causes it to produce branches. When the centre of a trunk, exposed to view by this horizontal section, is very watery, it is cauterized by a hot iron; by this operation its decay is prevented, and the axillary buds attract the sap of the lateral parts of the trunk, which is sufficient for their development.

This, which the results of cultivation show us, is also presented to us in nature, either accidentally—as for example, when the top of a stem is broken off by the wind—or naturally, when the flowering takes place.

The scapes of a great number of Endogens arise from the summit of the stems; as, for example, in *Yucca, Littœa*, several species of *Dracœna*, &c. When the flowering is over, and the seeds ripe, the sap is no longer attracted to the scape; and the stem, being arrested in its growth by the presence of this inert body, cannot elongate: then one of two things happens; either, as in most of our herbaceous Liliaceæ, the floral stem entirely perishes; or, as takes place in the woody Liliaceæ, the stem remains, the uppermost buds are developed and form true branches, several of which spring from the upper part of the stem. It is in this manner that the ramifications of *Yucca*, *Dracœna*, &c. are formed. I am inclined to believe that it is the same cause which produces the bifurcation of *Hyphæne coriacea*, which, in my opinion, bifurcates from a cause analogous to that which takes place in the Lilac and Chestnut.

The terminal decapitation of Endogenous stems, produced either by accident or by the flowering, appears to me the clearest of the causes of the ramification of several of them; but there are ramifications of Endogens which cannot be explained in this manner.

Thus we sometimes see buds and lateral branches developed in the lower parts of trunks; for example, towards the base of the stems of *Yucca*, or of the Date Palm, most frequently near the neck. It is very likely that these buds are favoured in their development either by the humidity of the soil, or by the slight stagnation of the descending sap which takes place at the neck. The origin of these adventitious buds is very obscure in Endogens; but if we think a little, it is not better known in our Exogenous trees, where this phenomenon is very frequent. Finally, there are Endogens where the axillary buds are developed with the greatest facility, although there is no appearance of any stagnation of the sap in the neighbouring parts; this, for example, takes place in *Asparagus*, *Ruscus*, &c. It is perhaps worthy of remark, that in the Asparageæ, which are much branched, the true leaves are abortive, and are reduced to simple scales: is it on account of this abortion of the leaf that the bud is developed? I think so, because of the coincidence of the facts, but I ought to confess that the cause is unknown to me. I will also add, that among Exogens similar phenomena are found; thus the leaves of the Barbary are transformed into spines, and all the buds are there developed into bundles of leaves; the leaves of Firs are transformed into scaly membranes, and the axillary buds are there developed into bundles of leaves. Among Endogens it is the same in the Asparageæ; the abortion of the leaves of *Asparagus*, and their changes into membranes, cause the development of the axillary buds into bundles of leaves and peduncles. The abortion of the leaves of the *Ruscus*, and their change into membranes, causes also the development of the bud into a flattened branch, in form resembling a leaf, by which name it has often been called; but it is afterwards seen to bear the bracts and flowers.

The observations which I have given, tend to make us conclude that the origin of the branches in Endogens is not perceptibly different from that of Exogens; but if they are more seldom seen here, it arises from the mass of the fibres being directed towards the summit: the terminal bud is larger and stronger, since it attracts the greatest part of the sap, which can only go to the lateral buds when the action of the terminal one is either destroyed by its obliteration, or balanced by the lateral stagnation of the sap. But these causes of the lateral stagnation of the sap are so much the more rare, as the external part of the trunk is more completely hardened; which explains why woody Endogens are less frequently branched than herbaceous ones.

This last consideration leads naturally to the explanation of one of the greatest anomalies of the growth of Endogens; viz., that some do not increase more in diameter after a given term; and that others seem to enlarge almost indefinitely. It appears to me clear that this difference is owing only to the degree of solidity or hardness which the tissue of each species acquires. When the old fibres, pushed towards the outside by the interposition of young ones at the centre, are hardened at a certain age, they serve as a solid sheath to all the central bundle, and the stem does not increase in diameter; this is what takes place in Palms. When these same fibres always preserve their flexibility or suppleness, so as to be able to be more or less distended by the interposition of the central fibres, the stem can always increase in diameter ; it is this which happens in herbaceous Liliaceæ, and almost all Endogens with soft tissue.

CHAPTER II.

OF THE ROOTS OF VASCULAR PLANTS.

Section I.

Comparison of Stems and Roots.

It is usual to call the Root, in ordinary language, the part of plants which is buried under ground ; and a celebrated botanist (Hedwig) wished to found upon the popular character the same definition of the root, which he considers as differing from the trunk only in its position, and he calls it *Truncus subterraneus.* But this definition is not correct; the stems of Ferns and Liliaceæ are sometimes aerial, at others subterranean;

the roots of House-leek *(Sempervivum)*, &c. are in some cases exposed to the air, in others buried under ground. We give a more exact idea of this organ in saying that the ROOT *(radix; racine)* is that part of the plant which, at its origin, tends to descend towards the centre of the earth with more or less energy. It is to this prevailing character of roots that some naturalists have made allusion when they have designated the root, in a general manner, under the name of *Descensus*. We have already seen that the point of junction of the root with the stem bears the name of the NECK; from it the root and stem proceed in opposite directions, so that the part of each of these organs nearest the neck is the oldest and usually the thickest part of the whole organ; it may be considered as the base, whatever be its position: the part of the root which is near the neck has been named the BASE or the HEAD of the root *(caput seu basis radicis)*; the part which is the most distant is designated by the name of the EXTREMITY of the root *(Caudex radicis*, Bose; *Caudex descendens*, Lin.) The root and stem form, as we have seen, two conical or cylindrical bodies, applied to one another by their bases, and growing by the apices; whence it necessarily results that the ramifications of these two organs are in an inverse direction one to another; the stems divide from the base upwards, and the roots from above downwards,—a difference which gives a very simple means of knowing them in certain doubtful cases.

A second character of Roots is that, excepting sometimes the extremity or spongiole, they do not become green, even when they are exposed to the air and light, the action of which almost always tends to render the leaves and stems green. When we see the constant whiteness of Roots, we are tempted to attribute it to the subterranean situation which seems peculiar to them; but the roots of Hyacinths, which are grown in transparent glasses,—those which shoot out from *Rhizophora*, &c.—those of plants which live in water, as *Ranuculus aquatilis*, preserve a white silvery appearance, with the exception of their extremity, which is sometimes greenish; whilst on the other hand the stems and leaves are almost entirely green. From the roots never being green, physiologists conclude that they do not decompose carbonic acid gas, and do not disengage any oxygen by the action of light. It is sufficient for me here to remark this phenomenon, as a proof of the difference of nature between roots and stems.

The anatomical structure of roots in general is distinguished from that of stems by two prominent characters:—1st, by the total absence of tracheæ; for all that has been heretofore said of them in roots is found to be incorrect;—2d, by the total asbence of stomata. The internal structure of roots, compared with that of stems, does not present any other perceptible difference in Endogens; we remark here, in the same manner, fibres composed of dotted or striped vessels, intermixed and surrounded with cellular tissue.

The similarity of the roots and stems is not found in Exogens; the medullary canal, which in these plants accompanies the stem through its whole length, stops suddenly at the neck, where it forms a *cul-de-sac*, the root being entirely devoid of pith; Grew and Malpighi observed it in some plants, such as the Borage, Chicory, Tobacco, &c. But although the roots of Exogens are devoid of pith, the medullary rays are found diverging from the centre to the circumference, and often more distinct than in the stem, as may be seen in the Radish and Carrot. The woody body of the roots of Exogens is smaller in proportion than in the stem; but the absence of the pith seems compensated by the great development of the cellular envelope of the bark. This development of the external cellular tissue appears to arise from this—viz. 1st, the growth of the woody body being less, the cortical body is not distended so much as in the stem; 2d, the subterranean position of roots, which tends to prevent the drying up and alteration of the external tissue. It is also to this position under ground that the dull and dark appearance of the epidermis of most of them ought to be ascribed.

We have seen, in speaking of stems, that their shoots grow throughout their whole length, until they absolutely cease to elongate. It is not the same with roots; they only lengthen by their extremities. If the position and respective distance of the lateral radicules be remarked, we can easily assure ourselves of this important fact. If dots of coloured varnish be marked upon the roots of the Hyacinth, the Bean, &c., or if small pieces of thread be fastened to them at equal distances, we see that all these marks remain at exactly the same distance at which they were placed, and the root is prolonged beyond them; whence we know that the roots only grow by their extremities. Duhamel, who first made this important experiment, has also remarked, that roots when cut never elongate,—a necessary consequence of their never lengthening but by the extremity. It is from this growth of roots solely by their extremities, and of young shoots by their whole length, that Mr. Knight has deduced the most ingenious and plausible explanation of the descending direction of roots, and the ascending one of stems.

The growth of roots in diameter takes place in each class of plants as in the stems themselves; thus the roots of Endogens are cylindrical processes, more or less thick; whilst those of Exogens are simple, or branched reversed cones.

If we continue to compare the roots with the branches, we more readily see that they are not organs of the same kind, as many authors have thought; their origin is entirely different, at least in Exogens: the branches spring from a bud, which is a process continuous with the bark, and which encloses the branch perfectly formed, but in miniature: true roots always arise without buds, and those which are produced by the bark of trees proceed from the lenticels, which never give origin to any branch. The branches are disposed in an order which is naturally regular, and analogous to that of the leaves; the roots arise most frequently without any determined order, or, if there be any, it is different from that of the branches; thus the French Bean has the leaves quincunx, and its roots, placed in water, shoot out radicules in four longitudinal rows: the *Mayanthemum* has two alternate leaves, and the radicules are verticillate around the central root. This disposition of the roots is subject to great variations, on account of the obstacles which the soil opposes to them. I have observed, in an experiment, that the roots of the same species of Willow are very different from one another, as regards the size, and also the disposition of the lateral radicules, according as they have been grown in pure water, or in that which was coloured by cochineal.

Branches often present articulations; roots are always devoid of them. Their knots even, when they exist, have only a very remote connexion with those of stems and branches.

We may also remark that roots are but little, if at all, subject to some of the causes which so strangely modify the appearance of stems and leaves. Thus they present hardly any kind of degeneration, either in limb, scale, tendril, or spine—phenomena so common in stems. The junction of roots with one another, or with other organs by tendrils, is either very rare, or perhaps does not exist; I have never seen, at least, any but doubtful examples. But the abortion of roots or radicules, entirely or in part, is a frequent phenomenon, and one which often deranges their symmetry of position.

Notwithstanding the numerous differences which we have enumerated between roots and stems, there are found some remarkable points of connexion between these two organs. Thus, for example, it is often difficult to fix with precision the point where the stem commences and the root ends. Modern authors all say that it is where the lobes or cotyledons are found at the period of germination: but this rule is evidently false; the cotyledons are leaves, and are always placed upon the ascending part or stem; the original neck is always situated below the cotyledons. By only viewing the germination of the Bean, this assertion is demonstrated. We shall revert to this, when we speak of the structure of the embryo.

A second circumstance, which has induced naturalists to admit the pretended identity of roots and stems, is the facility with which one of these organs gives origin to the other. Every time that in any part of the surface of a plant there is a stagnation of the juices, new productions are developed, as if these stagnant juices, meeting with latent germs, nourished them and obliged them to grow. If this part be surrounded by moist soil, or protected from the air and light, the new production is a root; if it be exposed to the air and light, it is a stem or branch. These principles are equally true, whether they be applied to the roots or stems, to the new productions which are formed naturally or artificially. Thus, if the extremity of a root be cut off, or if a ligature or incision be made in its bark, the juices are arrested above, and new roots are formed there; if, on the contrary, the wounded or cut root is found near the surface of the soil, instead of roots it is a young stem which is developed. It is for this reason, that on wounding roots extended horizontally, we cause trees to produce suckers.

What we have said with regard to roots equally applies to stems. If a ligature or incision be made on the bark of a tree, a rim is formed above it; if this be surrounded with earth and wet moss, it shoots out roots: this is the rationale of the manner by which cultivators multiply plants by layers. If a branch be cut off and placed in the ground, the part which is buried produces roots: this is what takes place in the multiplication of plants by cuttings. Lastly, if after having made an incision or ligature on the bark of a tree, the rim which is formed be allowed to be exposed to the air, it frequently develops new branches.

All that I have set forth with regard to those cases where the plants have been submitted to the influence of man, is presented in certain species as a necessary consequence of their organization. Thus, when a plant, instead of protruding its roots vertically into the earth, has them horizontally under the surface of the soil, each time these roots are found uncovered by the effect of the inequalities of the ground, they will be likely to produce new stems. This is what happens in roots said to be creeping; for example, those of *Ranunculus repens.* In the same manner, prostrate stems having one of their sides constantly exposed to the moisture of the soil, are disposed to shoot out roots from this side, if there be ever so little a stagnation of their juices. This is what takes place in the creeping stems of *Mesembryanthemum linguiforme*, *M. reptans*, &c.

The nodes or articulations of stems are points where nature has prepared beforehand a rest—a stagnation in the descending juices; and according as these nodes are exposed either to the shade, drought, or moisture, they produce branches or roots. It is for this reason that stems naturally knotty are more easily multiplied by layers or cuttings than others, as is seen in the Pink, the Vine, &c. When the cellular tissue of the bark of stems is very abundant or fleshy, the bark itself is constantly moist, and the juices are more stagnant there. Plants which present these characters have likewise a predisposition to shoot out roots, even when fully exposed to the air, as is seen in succulents, particularly in *Cactus*, *Crassula*, *Sedum*, &c. It is the same with roots: the tubercules which are developed upon some of them are kinds of stores or magazines of juice; these likewise have a singular tendency to emit new productions.

These facts, well known to all cultivators, have suggested to Duhamel and some others the idea of a bold experiment, from which false conclusions have often been drawn. A tree is selected which easily takes root by layers, such as the Willow; its top is bent towards the ground; the extremities of its branches are fastened down, and soon strike root there: when the roots are developed, the trunk of the tree is raised up so as to expose its old roots to the air, and place it in an inverted position; after some time it forms a new cyme furnished with leaves and branches. Mustel and some physiologists, who have spoken of this experiment of inverting trees, say that the branches are changed into roots, and the roots into branches, and they quote this fact as a decisive proof of the identity of these two organs; but this experiment, when better analysed, tends, on the contrary, to show their difference.

It is true that the branches here shoot out roots, but all the young shoots perish when they are put into the earth, and the new roots proceed entirely from points where no young branches existed; as for the old roots elevated into the air, all the small ones die, and adventitious buds are developed upon the old trunks.

We see, then, from all that I have set forth, that although there do exist resemblances between stems and roots, these two essential organs cannot by any means be confounded. Hedwig wished the root alone to be considered as the body of the plant, because in several perennial herbs the stem perishes each year, and the root alone retains the vitality of the individual; but it is certain, in this example, that the stem does not entirely perish; and, moreover, in the phenomena of cuttings, it is the reverse which takes place, since the stem develops new roots. The stem and root, then, ought to be considered as of equal importance, their union constituting the body of the plant. A plant, then, is composed of two cones (in Exogens), or of two cylinders (in Endogens), applied to each other by their bases, placed vertically, and elongating indefinitely by their extremities.

Section II.

Of the Parts of Roots, and of their various Forms.

Roots considered in a transverse section present, as we have before said, the same parts as stems, excepting that those of Exogens have no pith. Considered longitudinally, they are distinguished, like stems, into the trunk, and principal or secondary branches; but if these parts, which form as it were the framework of the root, differ but little from that of the stem, yet they present, in their extreme ramifications, a structure which is peculiar to them. They are completely devoid of the flat appendages of the stem which are known by the name of leaves; and most of them ramify, either laterally or by their extremities, into a multitude of very minute fibrils, which collectively constitute the CHEVELU. Roots are said to be FIBROUS when they have many slender branches, and this term is especially used in contradistinction to tuberous ones—that is to say, those which have distinct swellings in some part of their length.

The trunk and principal branches of the roots of Exogens are in the form of an elongated cone, the point of which is directed to the part most distant from the neck. Their increase in size differs but little from that of stems. The chevelu is formed of a multitude of very minute little fibrils, which appear cylindrical; they arise without any fixed order, especially where there is the least stagnation of juice. It is sufficient, for example, to cut off the extremity of a radical branch to cause a chevelu to be formed there.

The history of this kind of fibrils is as yet but little known, its subterranean position rendering observation difficult. Some, considering the chevelu as almost a peculiar organ, believe that it falls off each year, and is afterwards reproduced; but if it be possible that it dies and is destroyed, it is scarcely probable that it falls off in the strict sense of the word, for it has no articulation at its base. Others have thought that it only differs from the common branches of the root by its minuteness and multiplicity; that all its fibrils are equally suitable for being transformed into radical branches, but from the great number of them which are produced, there are only some which are thus developed, and that the others die more or less rapidly. This opinion, founded upon analogy with that which takes place in the branches of stems, appears to me for the present very reasonable; but I confess that sufficient proofs to clear up the point are wanting. Is it developed at a fixed period? Does it fall off, or is it destroyed within a given time? Is it capable of being changed into radical branches? What is its mode of growth in length and thickness? All these questions still require to be studied by direct observation.

Roots, considered as to their general form, present themselves under two very distinct appearances: the one kind, which I shall call with a SINGLE BASE (*à base unique*), have a conical trunk, simple or branched, but single at its base; and at the period of their first development their radicle, which is already entirely developed, only elongates or ramifies. These compose a great proportion of the roots which Richard has designated by the term EXORHIZÆ, and which exist in the greater number of Exogens. The others, which I shall call FASCICULATED, proceed in bundles, more or less distinct, from a common base, which is confounded with the neck of the plant, and may sometimes be taken for the base of the stem, and sometimes for the principal trunk of the root. These come exactly within the class of ENDORHIZÆ of Richard; they are found in the greatest number of Endogens, and in Exogens with fasciculated roots. The chevelu can exist in both classes of roots, but is much more frequent in the first. Let us pass rapidly in review the diversities of form in these two classes.

Among the roots which have a single origin, the principal differences can be derived from the degree of their ramifications; some are much branched, and usually abundantly provided with chevelus; they are called FIBROUS ROOTS; others, less frequent, are nearly simple and rather thick ; they have almost all their spongioles united into a single bundle at the extremity of the cone, and the cellular tissue of the bark is generally much dilated; they branch but little or not at all, and only bear here and there some fibrils, which are frequently entirely absent. They are called collectively, sometimes by the too vague name of TUBEROUS ROOTS, sometimes by the too restricted one of FUSIFORM ROOTS, and more correctly by that of SPINDLE-SHAPED *(Pivotantes)*, which makes allusion to their constant vertical direction; such are, for example, the roots of the Carrot, Turnip, Scorzonera, &c. The Bistort only differs from this class in having the principal trunk curiously twisted.

We may distinguish among simple roots two varieties of form:—1st, FUSIFORM ROOTS properly so called, or those which are nearly in the form of a spindle; such are those of the Carrot, &c., which have the form of an elongated cone. 2d, TURNIP-SHAPED ROOTS, or those which are very much swollen out under the neck, and abruptly taper to an elongated point; such are those of the Turnip, the Turnip-Radish, &c. The examples of the different varieties of Radish prove, that this form hardly differs from the preceding.

Roots which have several points of origin near the neck present also several distinct varieties of form:—1st, There are some, as those of Grasses, each fibre of which, distinct and simple at its commencement, so ramifies, that the divisions of each of them resemble the fibrous roots of the preceding class; the name fibrous has also been given to them, but it must be remarked, that under this denomination, roots of two classes are confounded. 2d, Several of these compound roots shoot from their neck simple cylindrical fibres, which descend, either remaining parallel, or slightly diverging;

such are those of the Hyacinth and most of the Liliaceæ. 3d, It often happens that the same neck gives origin, both to cylindrical fibres such as I have described, and to some fibres swollen up into round or oblong tubercules, simple, or slightly branched, full of fecula or mucilage, which seem to be reservoirs of nutriment intermixed with absorbing fibres: such are the fasciculated roots of most of the European Orchideæ, the Asphodels, &c. 4th, All the fibres which spring from the neck may present swellings more or less evident, and thus form bundles or bunches of oblong tubercules; such are those of the Dahlia, of several kinds of Ranunculus, &c. These four classes of compound roots are so nearly connected, that intermediate examples are found between all of them.

We designate collectively under the name of Tuberous Roots, all those which have swellings in any part of their length; the preceding enumeration has already proved that this phenomenon can exist in very different organizations. We may also add to these examples, that of lateral tubercules, which are developed here and there along fibrous roots with a single base; as for example in *Ornithopus perpusillus,* and several other herbaceous Papillionaceæ, and that of the swellings or nodosities which are observed here and there along the fibres of several fibrous roots, as in *Taxodium.* But these curious swellings seem so slightly connected with the generality of the structure, that they can be but little considered as classes of roots.

It must also be observed, that several tubercules which seem most evidently to arise from the root, are developed in reality along the lower branches of the stem buried under ground. Dunal was the first who proved that this took place in the Potato, and Turpin has confirmed it. This kind of tubercule will occupy our attention elsewhere.

The general direction of roots is, as we said at the commencement, to descend towards the centre of the earth; but if we compare them with one another, we see that they present differences in this respect; some, and these are in general those of the two great classes which are the least branched, have a tendency to descend almost vertically, and they depart very little from this direction. Branching roots, on the contrary, present in general a Tap-root *(pivot)* that is to say, the principal trunk of the root, which has a tendency to descend vertically; but the lateral branches are always obliged to separate more or less.

When they proceed from the principal trunk at a very acute angle, and tend successively to be directed towards the centre of the earth, they come under the general idea of roots; but it sometimes happens that they separate from the trunk at a right angle, or nearly so, and are prolonged, at least the upper ones, nearly parallel with the surface of the ground; we see this in the *Robinia*, the Elm, &c.; roots of this kind are said to be horizontal, spreading, or creeping. As they are found near the surface, they are often exposed, either by natural accidents or by the hand of man, and then they readily shoot out new stems. In this case the new individual, thus developed, may, spontaneously or artificially, be divided from that which gave origin to it, and grow separately. In roots of this kind the tap-root frequently elongates but little, and sometimes even dries up or becomes hard at its extremity.

Section III.

Of Subterranean and Root-like Stems or Branches.

The number of true creeping roots is smaller than is generally believed; for in several cases, this name is given to true branches of the stem, which, springing from very near the neck, are developed underground, or on a level with the surface, as is the property of all stems in similar circumstances; it is thus that what are called roots in *Triticum repens* and *Panicum Dactylon*, are true subterranean branches of the stem which shoot out radicules from each of their knots. *Carex arenaria* and several other Cyperaceæ present analogous examples; it is thus that the pretended roots which the subterranean pods of *Vicia amphicarpa* and *Lathyrus amphicarpos* bear, are only branches of the stem buried under ground and among stones. It is also thus that the root-like branches which, in the Potato, bear the tubercules, are only the lower branches; and therefore it is found advantageous to bank up the bottoms of the stems of this plant, because by this process the number of these subterranean branches is increased. Sometimes the base of the stem itself forms a kind of horizontal trunk, which elongates by one of its extremities, gradually perishes at the end most distant from the neck, and shoots out radical fibres throughout the whole of its lower surface: this takes place in a great number of aquatic plants, such as the Water Lilies, *Potamogeton*, &c.; we find it also in the herbaceous Ferns. Sometimes, lastly, the principal stem, without changing its direction, is gradually buried by the raising up of the earth around it, and takes the appearance, and also in some respects the structure, of a root. De La Roche has shown a very remarkable example of this phenomenon in the Eryngo, and I have especially verified it in *Eryngium maritimum,* which grows in the sand on the sea-shore; its stem is sometimes buried several feet in depth, and takes throughout the whole of this length the appearance of a root; the same thing happens in the *Echinophora* in the same situation, and I have mentioned above the example of the *Salix herbacea,* which, by the elevation of certain Alpine soils, becomes a kind of subterranean tree; in these different cases the direction of the branches towards the upper side is the character by which we can most readily distinguish these buried stems from true roots.

Section IV.

Of Adventitious Roots.

Under the name of Adventitious Roots I designate those radical processes which, instead of springing from the radical trunks, are developed upon the stem and branches, or sometimes upon other organs. These roots (at least in Exogenous trees) proceed from the Lenticels, which we have described in Book I. Chap. X. Sometimes, as in *Sedum altissimum,* we see them spring from the old cicatrices. As for Exogenous herbs, and those trees of this class in which no lenticels have been discovered, and also with regard to Endogens, the adventitious roots may proceed from almost every part of the surface, and their development is caused by the lengthened contact of moisture with a part of the surface disposed to this production of roots; it is favoured by darkness, heat, and especially by a small quantity of nourishment. These roots arise in preference from knots, tubercles, and in general all parts where there is any deposit of nutritive matter. The art of making them to be produced constitutes the operation of laying, &c. When the adventitious roots arise in the air, they most frequently present themselves under the form of cylindrical filaments, of a silvery white colour, descending vertically towards the ground; we see this in *Ficus elastica*, *Clusia rosea*, *Rhizophora*, succulent plants, &c. The length of these filaments reaches, in *Clusia* and *Rhizophora*, from eighty to one hundred feet. Sometimes they ramify even when they are produced in the air, as for example in *Rhus radicans;* this ramification is especially frequent when the roots are produced in wet moss or earth.

Turpin has observed that adventitious roots do not augment in diameter before they reach the soil; but, as soon as they begin to absorb nourishment, they give origin to lateral roots, and they themselves grow in a remarkable degree.

There are some plants in which adventitious roots alone are found; such are those which undergo, at the period of germination, that kind of destruction of their base which I have spoken of in the preceding section, and whence it results that the true root is not developed, and that the base of the stem, usually buried in the earth, takes the appearance of a root; this stem shoots out then a multitude of adventitious roots, and it is with these alone that the plant is provided. This phenomenon frequently takes place in the subterranean stems of herbaceous Ferns, and in a great number of Monocotyledons, such as *Allium senescens*, &c. It is found in Dicotyledons—in the Water Lily.

Leaves are capable of producing adventitious roots, especially along their petioles; this is observed in particular in leaves of a firm texture, such as those of the Orange, *Ficus elastica*, &c. By this property we are sometimes enabled to multiply these species.

Section V.

Of the Functions of Roots.

The functions essentially peculiar to roots are—1st, to absorb nourishment; 2d, to fix the plant to the ground. The union of these two uses is necessary for an organ deserving the name of root; thus in certain plants, such as the *Fuci* or the Ivy, we observe root-like appendages, which fix them to solid bodies, but which do not serve to absorb nourishment; these are not roots, but Cramps *(crampons)*. In others, such as the Dodder, certain peculiar tubercles absorb their nourishment, but do not serve to fix them to the soil; these are not roots, but Suckers. Thus, every organ which unites the two conditions above mentioned is a root, and all roots present this double function, but with variations and modifications, which deserve a detailed examination.

The absorption of juices by the roots takes place solely by the extremity of each radical fibril, or, which is to say the same thing, by the spongioles which terminate each of their ramifications. Duhamel had some idea of this when he remarked that young trees exhaust the earth very near their trunk, whilst old ones with horizontal roots, such as the Elms on the sides of great roads, produce this exhaustion at a distance from their trunk, the more considerable in proportion as they are larger. Anatomists have confirmed this opinion, in remarking the longitudinal direction of the fibres, and the thickness of the cellular envelope, which prevents the juices from reaching them laterally. Lastly, Senebier has shown it by a direct experiment made upon the nearly simple roots of the Carrot: he plunged one entirely into water, and of another he only put the extremity in; in both cases he saw that the absorption was perceptibly equal: afterwards he took two others, putting the extremity of one into the water, and plunging in the whole surface of the other, with the exception of its extremity, which was raised in such a manner as to be out of the water; the first absorbed as usual, but the second did not in the least. It is certain, then, that the absorption of roots only takes place by their extremities; we may here mention that it is, then, at the extremities of the roots, and not at the base of the trunk, that we ought to apply water, manure, and in general all the substances which we wish plants to absorb.

In the natural state of things, roots always having a tendency to proceed away from their point of origin, either in a vertical direction or in a horizontal one, constantly meet with new strata of earth, the nourishment of which has not been exhausted; and as to natural watering, as there is generally a certain relation between the size of the cyme of a tree and the length of its natural roots, it is found that the rain, after having fallen upon the cyme, drops naturally at the most convenient distance from the trunk to reach the extremity of the roots.

The division of the radical fibres has the utility of separating the spongioles, in such a manner that each of them placed in a situation distinct from the neighbouring ones finds some sap to draw up. Those which have few or no ramifications have all their spongioles placed at the same point; whence it results;—1st, that they ought to exhaust of juices this fixed place in a more complete manner, but leave the surrounding earth more intact;—2d, that the accidents which reach their extremity are more serious than is the case with fibrous roots, since they affect at the same time all the mouths of the plant. This circumstance ought to make us think that tuberous roots are much more delicate than others; but it is amply compensated by another peculiarity in their structure: all of them enclose a more or less considerable deposit of nutritious matter, either feculent or mucilaginous; whence it results that they can, in certain cases, furnish the plant with nourishment for some time, when absorption by the exterior is stopped, just as animals provided with depositions of fat can resist abstinence longer than others. It is a law, usually tolerably true, as to the general organization of roots, that the less numerous and dispersed the spongioles are, the more they present deposits of nutriment prepared beforehand.

Spindle-shaped, or deep roots having their spongioles united near the lower extremity and always having a tendency to elongate vertically, ought to fear less than all others both the severe frosts of winter and the great drought of summer, because their action is exercised in a stratum of earth less submitted to the influence of the atmosphere. Creeping roots present the opposite extreme; they are more affected by too cold or too dry temperatures, but they also profit more rapidly from favourable atmospheric influences.

The use of roots with regard to the manner in which they fix the plant in the earth is also singularly favoured by their ramifications, by which the points of attachment are multiplied—by their vertical direction—or by their size. In general, if individuals of the same species be considered, there is a constant relation between the size of the stem or branches and that of the root; but this does not exist in different species. Thus, a great tree, as the Fir, has its roots smaller, not only relatively, but in certain situations absolutely speaking, than the Lucerne or such other smaller herb than itself.

Generally, spindle-shaped roots do not descend beyond a few feet in depth, because below this limit they either meet with strata of earth too hard for them to pierce, or they cannot sufficiently enjoy the influences of the atmosphere.

Some spindle-rooted plants, such as *Eryngium*, although their root is sometimes found buried at a very great depth, do not form a real exception to this rule; for more frequently, especially on downs, as I have said above, it is the earth which is elevated, and not the plant which has descended; and the greatest part of that which is taken for the root is formed by true stems, to which their remaining underground has given the appearance of roots.

Horizontal or creeping roots, being situated in such a manner as to be prolonged into lighter earth, and near the influences of the atmosphere, are those which take the greatest dimensions in length; thus the roots of the Elm, *Robinia pseud-acacia*, *Ailantus* or Sumach, are sometimes prolonged some hundred feet beyond the trunks which gave origin to them; they are seen to insinuate themselves under buildings, between the cracks of walls, and often to produce extraordinary dilapidations at a great distance from their origin: when the young radical fibrils creep into the imperceptible cracks of rocks or walls, and as they there find a favourable nourishment, they are slowly developed, but with sufficient force to raise up enormous weights, and to move masses which would seem immovable. When roots are but little branched, or divided into fibres too thick to insinuate themselves into cracks, or when they meet with invincible obstacles, it happens either that the root takes a very different direction from its usual one, or that the entire tree is more or less raised above the soil by the growth of its roots which, not being able to pierce the obstacle placed before them, react upon the tree itself. It is thus that we often see Palms, cultivated in tubs, raise themselves up above the surface of the soil.

Roots spread more easily in light earth; whence it results—1st, that if individuals of the same species be compared, they are the more firmly attached to the soil, as the soil itself is more friable and as the trees more require it;—2d, that if different species be compared, those with long roots have a greater tendency to grow in light earth; and those with short ones, which in a light soil would readily be uprooted by the wind, can maintain themselves in a more compact soil.

We have been examining the two essential functions of roots viz.—those of drawing up nourishment, and of fixing the plant to the soil; it now remains for us to say a few words of two less general uses, which can only be carefully analyzed in Physiology.

The first, which I have already transitorily mentioned, is that several tuberous roots present deposits of nourishment prepared beforehand, and which nourish the plant, either in accidental cases, where nourishment ceases to reach it; or at periods when the leaves, not having as yet been developed, are not able to elaborate it, as at the commencement of spring; or, lastly, at the time when the ripening of the seeds requires a superabundance of nutritive matter.

Several roots, it is said, transude by their extremities excrementitial juices, the origin and history of which are still but little known; but they appear to be the cause of several important phenomena. These excretions of roots have been particularly seen by Bruemans, and they deserve the greatest attention on the part of Physiologists.

CHAPTER III.

OF THE LEAVES OF VASCULAR PLANTS.

SECTION I.

Of the General Structure of Leaves.

THE Leaves are, as every one knows, those expansions, generally flat, of forms so various, which spring laterally from the stem or branches of plants, and form one of their principal ornaments. Turpin calls them in a more general manner by the name of the *appendicular organs of plants,* joining under this term not only the leaves in their natural state, but all the other lateral organs of stems, which are only modifications of them, as we shall shortly see. We shall here consider them in their ordinary state.

When they are studied with regard to Physiology, it is found that they are the principal organs of the aqueous evaporation, of the decomposition of the gases and juices, and consequently the most essential agents of nutrition. If we consider them anatomically, as it is here our intention to do, we perceive that a leaf is the expansion or spreading out of one or several fibres, which, detaching themselves or springing from the mass of the stem, spread out in such a manner that each vessel is separated from all the others, and has its orifice more or less isolated. If this fundamental idea is just, its development ought to explain to us the entire structure of the leaf, and the variations of which it is susceptible.

As long as the fibres which spring from the stem form a bundle but little or not at all spreading, and differing from the state of the leaf properly so called, to this bundle the name of PETIOLE is given: it is the same organ which is commonly called the stalk of the leaf. In contradistinction to the petiole, we call the LIMB all the part where the fibres are more or less diverging, and where their spreading out is more or less perceptible. There are some leaves the expansion of which commences at the same point where the fibres quit the stem: these are said to be SESSILE, in contradistinction to PETIOLATED leaves, or those furnished with petioles. We shall see hereafter that there are also leaves devoid of the limb, and reduced to a simple petiole.

As leaves are furnished with or devoid of the petiole, they may be articulated at their base with the stem or branch which bears them, and then they are said to be ARTICULATED WITH THE STEM;—or the petiole, or the limb when it is absent, may be united to the stem without an articulation; we say then that the leaves are CONTINUOUS WITH THE STEM. The first organization principally occurs in leaves with ramifying nerves, and petioles which are not sheathing; the second, in leaves with simple nerves, sheathing petioles, or an embracing limb. We shall see, by and by, that this character is connected in an important manner with the duration of leaves.

When the parts of a leaf are articulated with one another, we give to them collectively the name of a COMPOUND LEAF, and reserve that of SIMPLE LEAVES for those all the parts of which are continuous. The partial limbs of compound leaves bear the name of LEAFLETS.

In the limb, whether sessile or petiolated, are distinguished at first the NERVES; that is to say, the bundles of fibres which separate from one another at the base of the limb, and form as it were the skeleton. The first bundles which spring from the base of the limb, or the prolongation of the petiole, bear the name of PRIMARY NERVES; their immediate ramifications are called SECONDARY NERVES; the divisions of these are the TERTIARY NERVES; and several orders of them might be recognised, until we arrive at the last ramifications of the fibrous bundles in which the vessels are found isolated. All these ramifications collectively form the fibrous tissue, which is as it were the skeleton of the leaf.

The interval between the nerves—the primary, secondary, &c. is more or less filled up by the development of cellular tissue; and it is this, strictly speaking, which forms the PARENCHYMA of the leaf: but it must be remarked, in order to comprehend the customary sense of terms employed in Botany—1st, that the nerves which project but little or not all, but yet are visible, are called VEINS; and 2d, that under the name of Parenchyma is generally confounded not only the cellular tissue, properly so called, but also the last ramifications of the fibrous tissue, or the scarcely apparent veins.

The nerves of leaves differ much in their thickness, sometimes being very considerable, at others scarcely or not at all projecting beyond the parenchyma. In general they go on regularly diminishing in thickness from the base of the limb to their extremities. I do not know that this law has more than a very small number of exceptions: the most remarkable is the leaf of an unknown tree from Cayenne, of which I possess branches in my Herbarium, and where the nerves are seen swollen into kinds of oblong tubercules along their ramifications.

Care must be taken not to confound with the true nerves, certain lines produced upon some leaves in their infancy by the impression of the median nerve, or the border of other leaves. This is observed in a singular manner in *Ocotea* (Pl. 10, fig. 1), where the leaf, independently of its ordinary nerves, presents an oblique line. The straightness, obliquity, and variety of position of this line, are circumstances which clearly distinguish it from true nerves.

When the fibres spread out to form the limb of the leaf, they can do it in two different manners (whether it takes place at the extremity of the petiole, or at their issuing out of the stem); they may either spread out upon the same plane, as is most frequently the case—this forms the common flat leaves; or they may diverge in all directions, forming the cylindrical, swollen, or triangular leaves of certain succulent plants. This last disposition of the nerves can so easily be referred to the division of flat leaves, that it will be sufficient for us to explain these latter in detail.

The limb of a flat leaf presents three distinct parts: —1st, the upper surface;—2d, the lower one;—3d, the intermediate space which, by analogy with Carpological language, I shall call the MESOPHYLLUM. We will first examine this last organ, which constitutes the body of the leaf.

The mesophyllum is formed of all the ramifications of the nerves, and of the cellular tissue which fills up the intervals between them and surrounds them: the less these ramifications separate from the same plane, the thinner is the leaf; on the contrary, the more they separate from this plane, the thicker will it be, and the more must the cellular tissue be developed to fill up the intervals.

The number of fibres in a leaf of a given size is that which most influences its texture: when they are very numerous, the cellular tissue occupies proportionally a less space, and the leaf is composed of a firmer, a more fibrous tissue. When the fibres are fewer or more separated, the cellular tissue is more developed, and the leaf is softer or more fleshy. If the leaves of the Fir and the Orange, on the one hand, be compared with those of the Tobacco and the Ficoids, on the other, we shall have nearly the extremes of these differences; it is also met with in the leaves of the same species; thus, of two similar plants, that which grows in a more fertile soil will have its leaves softer,—the natural number of the fibres is not changed, but the development of the cellular tissue is greater; that which grows in a barren soil will have, with the same number of fibres, a less developed cellular tissue. The leaves of the same individual may present analogous differences, according as they are more or less favoured in their growth.

These considerations, so elementary that it would perhaps appear better to omit them, give us the reason of some facts of delicate anatomy; thus, for example: —1st, we have seen, in speaking of the Stomata, that they appear to be the upper orifices of the sap-vessels; consequently, the larger the number of fibres, or in other terms, the more fibrous a leaf is, the proportional number of stomata will be greater in a given space; thus, there are as many as fifty or sixty on the leaves of the Orange, in the same space as in the *Mesembryanthemum* there are but five or six. 2d, we have seen, in speaking of Hairs, that, when they exist, they always arise along the nerves or their ramifications; consequently when a leaf is young, its nerves existing already formed, the hairs are more numerous in a given space, and in proportion as its development goes on, the cellular tissue enlarging interposes itself between the fibres, separates them, and at the same time the hairs; so that, even when they are not thrown off, as sometimes happens, the old leaves appear less hairy than young ones, and the leaves of plants growing in a fertile soil are less so than those which have grown in a sterile place; consequently, in general, cultivated plants are less hairy than wild ones.

The mesophyllum comprehends probably two systems of organs, but anatomy has not yet been able to distinguish them, viz.—1st, a system which receives the ascending sap, brings it into contact with the air for its elaboration, and permits the exhalation of the superabundant parts;—2d, a system which receives the elaborated sap and conducts it back to the stem, where it serves for nutrition. Physiological phenomena prove the existence of these two functions in leaves, but anatomical observation has not distinguished them; it is not even known if the two functions are performed alternately by the same organs, or if, which is more likely, they are the consequence of two different systems.

The two surfaces of leaves are composed of true cuticles, and all that we have said of that organ is applicable to them; in particular, it may be observed, on comparing species together, that the cuticles are the more easily raised as the fibrous tissue is less abundant in proportion than the cellular, and consequently as the number of stomata of one surface is less. In other terms, the cuticle is easily raised in plants where the cellular tissue is abundant; thus, very herbaceous leaves are more easy to peel than fibrous ones; but when the different surfaces of the same species are compared, this law is modified by a contrary one—viz. the cuticles of leaves are more easily raised where the most stomata are found, because the evaporation being greater there, the external membrane becomes more firm. Thus, in each leaf, the cuticle which is easily raised, is that where one ought to expect to find the stomata. These two laws, in appearance contradictory, modify one another, and it is from their combination that all the different degrees of adherence of the cuticles of leaves result.

The two surfaces are often very different from each other; generally the upper surface presents the nerves scarcely projecting, and consequently has a more even appearance; it has a less quantity of hairs; it is frequently devoid of stomata, or has a less number than the lower surface; consequently it has also its cuticle more adherent, whence it results that its colour is of a more intense green. These characters of the upper surface of leaves are especially very decided in most trees—the Pear, &c. for example. The lower surface presents most frequently opposite characters to the preceding; its nerves are more projecting, and it bears a greater number of hairs;* it alone is provided with stomata, or at least it bears a greater number than the upper surface; lastly, its cuticle is less adherent, whence it results that the colour is generally paler.

The differences between the two surfaces present peculiar phenomena in floating leaves, such as those of the Water Lily: these have the upper surface shining and green, and the lower pale and dull, but nevertheless the upper surface, being alone exposed to the air, alone has stomata.

Not unfrequently the two surfaces almost exactly resemble each other, both as regards the number of the

* This observation, which is generally true, is not so in all cases; thus, we sometimes see *Astragalus Hypoglottis* with its leaflets hairy above and smooth beneath. The leaves of *Passerina hirsuta* are woolly on the upper surface and smooth on the lower; but the number of these exceptions is very limited.

stomata, the appearance of the nerves, the degree of their greenness, and the appearance of their tissue; we observe this in several herbaceous plants.

But as the two surfaces present an aspect either very different or very similar, they do not appear less destined to perform a special function, for their natural position cannot be disturbed. If one tries to turn a leaf so as to direct its lower surface upwards and its upper downwards, it always tends to regain its natural position; and if it be retained by any mechanical means in this unnatural position, it dies very soon. In trees with naturally drooping branches, the leaves turn round more or less completely to regain their true position. This fact appears to indicate that the return of leaves placed in a position contrary to their natural one, is not simply owing, as might be believed, to their petiole endeavouring to untwist itself by the mechanical effect of elasticity, for here their petiole twists spontaneously to place the two surfaces in the position which is proper for them. There are also some leaves which, without belonging to drooping branches, are naturally placed in a position contrary to that which seems natural; thus, Meyer has observed this in the limb of the leaves of *Festuca trinervata*, and some other grasses. The cause of this phenomenon is as yet unknown.

The edge of the leaf is caused by the commissure of the two cuticles: in flat leaves there is no difficulty in recognising it, but in three-cornered ones, such as those of *Mesembryanthemum acinaciforme*, the upper surface is represented by the upper part of the triangle, although it may sometimes be very narrow; the lower angle or the keel represents the longitudinal nerve; the two lower surfaces are the two sides of the lower surface of the leaf; the upper angles are consequently the commissures of the two surfaces, that is to say, the true edges of the leaf. In cylindrical leaves, as those of *Mesembryanthemum calamiforme,* neither the edges nor the surfaces can be distinguished. Lastly, there are some leaves so folded upon themselves, that all their external part is formed by the lower surface; such are those of the Iris, which are called Ensiform; they seem flat like ordinary leaves, but compressed laterally, instead of being depressed; they are in reality folded one half upon the other; their lower angle is the middle nerve, the upper one is the junction of the two edges.

The edges of leaves present some peculiarities worthy of notice; they are frequently indurated: when they bear hairs, these are generally stiffer than ordinarily, and have received the name of Ciliæ; these ciliæ indicate the existence of a marginal nerve. Sometimes, especially in leaves with ramifying nerves, the ramifications are more or less directed towards the edges, and their extremity frequently presents a point or small tubercle, from which, in favourable cases, may arise either roots, or even young individuals, as in *Bryophyllum Calycinum.* It is also from points analogous as to their position, that the marginal spines are sometimes prolonged. But these facts can only become clear after we have examined the disposition of the nerves.

Section II.

Of the Distinction between the Petiole and the Limb of Leaves.

The Petiole, or, as it is commonly called, the stalk of the leaf, is not the prolongation of the limb, as the popular term would seem to indicate, but, on the contrary, the base or support of the limb, the as yet unexpanded bundle of the fibres of the leaf. Most frequently a leaf is composed of a limb and petiole ; sometimes it is devoid of one or the other : in these different cases, the petiole assumes various appearances, and it is often difficult to recognise its existence among the many forms it takes. In order to follow it in all its metamorphoses, we will first study it in leaves with ramifying nerves, where its structure is more appreciable, and afterwards in those with simple ones.

It is among leaves with ramifying nerves, or those of Dicotyledons, that the peculiar structure of the petiole is most evident, and in which it can be studied under its most simple form ; it is there presented under that of an elongated and nearly cylindrical bundle of fibres; its length is very variable—sometimes it is longer than the limb, sometimes so short that it may be said not to exist. Its form is either entirely cylindrical,—or slightly depressed, —or hollowed into a channel, the upper side being plane or concave, and the lower raised up into a dorsal angle,— or, lastly, much compressed, as is seen in the Poplar, in which this form of the petiole causes the extreme mobility of the leaves. In all these cases the petiole is simple, composed of a certain number of fibres close to one another, intermixed with elongated cellular tissue ; it never bears stomata, but, like the nerves of which it is the base, it is often furnished with hairs or glands; its colour is usually pale, its texture firm ; it does not decompose carbonic acid, and assists but slightly, if at all, in the evaporation of water.

This ordinary form of the petiole is modified by different circumstances.

1st. When the edge of the petiole is flattened, it sometimes happens that it spreads out laterally into a flat and foliaceous portion, perfectly resembling the parenchyma of the limb. It is said then that the petiole is BORDERED: such is, for example, the petiole of *Lathyrus articulatus*. This marginal limb is endowed with all the properties of the ordinary limb, and may replace it, physiologically speaking. It is likely that that which is called the leaf in the *Nepenthes*, is a bordered petiole, and that the true limb is the terminal cup. It is possible that, in the *Dionæa*, the name of Bordered Petiole ought to be given to the lower part of the leaf, and that of Limb to be reserved for the two irritable lobes. The marginal limb of bordered petioles differs in general from the ordinary limb, in not having lateral projecting nerves, but only anastomosing veins. In compound leaves, if the petiole be bordered, as frequently happens, the border is interrupted at each articulation when the leaflets are opposite. Thus, for example, in some species of *Inga*, or in *Fagara pterota*, the petiole is composed of as many joints as there are pairs of leaflets, and each joint is bordered by a foliaceous wing.

Let us suppose now, as frequent examples are found among compound leaves, that all the lateral leaflets are wanting; two things will happen:—If there be no terminal leaflet, the leaf will be found composed of joints placed end to end; this is what is called a LOMENTACEOUS LEAF, and of which a Bignonia (Pl. 10, fig. 2), discovered in Madagascar by Noronha, affords an example. Such a leaf is nothing but a petiole composed of bordered joints, the leaflets of which have not been developed. If the terminal leaflet exist, there is sometimes a bordered petiole terminated by a single leaflet; this takes place in the Orange, Citron, *Desmodium triquetrum* (Pl. 10, fig. 3), &c. Sometimes a cylindrical petiole, terminated by a leaflet also cylindrical, as in *Sarcophyllum* (Pl. 10, fig. 4); sometimes, and this is the case most frequently, an ordinary petiole, terminated by a simple leaflet, as is seen in several species of *Ononis*, &c. These different examples may prove, in some degree, how easy it is to confound the limb, properly so called, with the bordered petiole. But this confusion is of but little importance; for it may be said that the longitudinal nerve of the limb being a prolongation of the petiole, all limbs are only bordered petioles.

2d. There are some Dicotyledons, such as the greatest number of Umbelliferæ and Ranunculaceæ, in which the fibres that ought to form the petiole, instead of being distributed at their origin in a compact bundle, arise side by side in a transverse series, which occupies either all the circumference of the branch, or a remarkable portion of it. The base of the petiole is then flat, and more or less sheathing; but soon the petiolary fibres come nearer together, and form bundles as usual, and the upper part of the petiole does not differ from those with a round base. The sheath, although flat, preserves the characters of the petiole; it has few or no stomata, and does not always decompose carbonic acid gas.

This expansion of the base of the petiole takes place in a very high degree in the upper leaves of *Lepidium perfoliatum*, *Bupleurum perfoliatum*, &c. where it entirely takes the appearance of a foliaceous limb.

In the upper part of the stems of the Umbelliferæ, these petiolary sheaths are frequently seen to exist, although they have not been able to produce either the foliaceous limb, or, sometimes, the cylindrical part of the petiole. If one found an umbelliferous plant, which had only these sheaths, he would be inclined to give them the name of leaves, although they evidently are sheathing petioles; thus it is that we call leaves, in *Lathyrus Nissolia*, true petiolary sheaths, which, when they are entirely devoid of the limb, dilate still more than ordinarily, and perform in some respects the physiological function of leaves. It is possible that to this class of phenomena the singular structure of *Cyclamen linearifolium* ought to be referred. Most bracts and several scales of buds are degenerations of leaves analogous to those which I have been pointing out. If the scales or rudiments of leaves of *Monotropa* be compared with the base of the petioles of *Pyrola*, we shall consider them as petiolary sheaths, and, by analogy, the same ought to be admitted with respect to *Orobanche*, *Lathræa*, &c.

The petiole of the Polygoneæ is also furnished at its base with a membranous and sheathing appendage, which is called the OCHREA; but its anatomical history still presents some obscurity, and it also may almost be considered as a petiolary sheath, or as formed by intra-axillary stipules united together.

3d. It sometimes happens, especially when the limb is not developed, that the petiole, without being sheathing at its base, dilates throughout its entire length, assuming a state intermediate between foliaceous and petiolary, and then it receives the name of PHYLLODIUM; thus, when most of the Acacias of New Holland are examined, we see that in their infancy they present bi-pinnate leaves, with a slender, nearly cylindrical petiole. As the plant advances in age, the number of leaflets diminishes, the petiole dilates, and by degrees the leaflets completely disappear, and all the leaves are reduced to petioles dilated into Phyllodia. These are flat, coriaceous, firm, always entire at their edges, provided with longitudinal nerves, which are the traces of the fibres of which the petiole is composed, and constantly placed upon the stem in a contrary direction to true leaves; that is to say, their plane is nearly vertical instead of being horizontal; or, in other terms, their surfaces are lateral, instead of one being superior and the other inferior. There are some species which, during the whole of their lives, bear a mixture of petioles furnished with the ordinary leaflets, and of petioles transformed into Phyllodia; such are *Acacia heterophylla*, (Pl. 6, figs. 2, 3, 4, 5,) *A. Sophoræ*, &c. Some bear upon their superior edge one or two glands, which indicate the place where the ramifications bearing the leaflets ought to take their origin. All these characters show their petiolary nature; but the fibres of these petioles are sufficiently separated to admit a small quantity of parenchyma, and to bear stomata; whence it results that these organs perform physiologically the function of a limb. Some analogous transformations take place in some species of *Oxalis*, as *O. Bupleurifolia* and *O. fruticosa*.

That which we have clearly seen to take place in following the history of *Acacia heterophylla* I presume does so equally in some other less evident cases. Thus, for example, the leaves of several species of *Bupleurum* appear to me to be true Phyllodia; they, in fact, completely resemble those of the Acacias, and are particularly analogous to them, both in their hard extremity, which denotes an abortion, and by their vertical position, which is hardly ever met with in the true limbs of leaves. These reasons are corroborated by the example of *Bupleurum difforme;* this name has been given to the only species which reveals the structure of the leaves of this singular genus. In its young state it has, like the Acacias, leaves with the limb developed, and cut out in the manner of the Umbelliferæ: when full-grown it has only Phyllodia. It is also to this or the preceding class that I am inclined to refer the leaves of *Ranunculus gramineus*, and those of all Dicotyledons which seem provided with longitudinal and parallel nerves.

4th. It happens more seldom in some plants that the leaflets are abortive, and that the petioles remain naked and cylindrical, without elongating into tendrils, or changing into a spine. This takes place, for example, in *Lebeckia nuda*, (Pl. 10, fig. 5,) and *Indigofera juncea*, which some, for this reason, have said to be APHYLLOUS.

5th. When in compound leaves the extremity of the petiole does not bear a leaflet, it then frequently happens that, remaining soft, it is prolonged either into a little process, or a true and branching tendril, as is seen in *Orobus*, *Vicia*, *Lathyrus*, &c.; sometimes even all the lateral leaflets are abortive, and the leaf is not composed of more than a petiole transformed into a tendril, as in *Lathyrus aphaca;* but in this example, as well as in the Phyllodium, the leaves of the young plant frequently present leaflets which are afterwards wanting.

6th. Finally, in the same classes of compound leaves where the terminal leaflet is absent, it often happens that the petiole hardens into a spine at its extremity, as is seen in *Astragalus*. I do not insist upon these two last degenerations, as I shall revert to them in a more general point of view in Book IV. Chap. I. and II.

If we now consider in the same manner leaves with simple nerves, or those of Phanerogamous Monocotyledons, we shall find analogous facts. The structure of their petiole, when it exists, is modified by the disposition of the fibres: they are always placed side by side, so that the base of the petiole is more or less sheathing; above the base these fibres are sometimes united into a triangular or semi-cylindrical petiole, as, for example, in several species of *Hemerocallis*, *Alisma*, &c. In almost all the Palms we find also a petiole nearly triangular, expanded at its base into a kind of dry sheath, the fibres of which are very visible, and often denuded of parenchyma; but frequently, also, the petiole is sheathing and foliaceous; we see this particularly in the Gramineæ, where it bears the name of SHEATH. This cylindrical sheath surrounds the stem in a considerable part of its extent: it is most frequently split throughout its whole length, because the two borders remain free. It bears externally at its extremity a limb with parallel nerves, separated from the sheath by a kind of hard strangulation. The apex of this sheath is prolonged interiorly into a short, scaly, and, most frequently, erect lamina, which has received the name of the LIGULE. The Cyperaceæ only differ from most of the Gramineæ, with regard to their foliage, in this: 1st, that their sheath is almost always entire; that is to say, that the two borders are joined together so as to form a true cylindrical tube; 2d, that the ligule is often absent; and 3d, that the limb is less distinct from the sheath.

There are examples in which the simultaneous and constant existence of the limb and petiole hardly leaves any doubt upon the nature of either of them; but there are doubtful cases which deserve particular mention. If we examine the common *Sagittaria*, we shall find that, when it grows out of the water, all its leaves have the limb and petiole distinct; when it grows in water, its limb is nearly always abortive, and its petiole, instead of being triangular or cylindrical, takes the appearance of a flat foliaceous ribbon, terminated by a small callosity, analogous to that which is observed in the petioles of Dicotyledons, where the limb is abortive; it is not rare to find plants which bear these two kinds of leaves at once. The same phenomenon happens in the Potamogetons, where the leaves floating on the water have a similar limb, whilst the submerged ones are reduced to a membranous petiole. The comparison of the different species of *Strelitzia* of the gardens presents an analogous result; their petiole is sheathing at the base, afterwards cylindrical, tapering a little upwards; at its extremity it bears a very distinct limb, which is large in *Strelitzia regina,* half the size in *S. parvifolia,* and completely absent in *S. juncea,* in which the organs which are called leaves are petioles.

To the foliaceous organs of Monocotyledons, which are of the same nature throughout, and in which it is impossible to distinguish a petiole or limb, such as the Hyacinth or Aloë, &c. the name of leaves has been given, which would seem to indicate that they are regarded as sessile limbs; but as this idea has been admitted without any examination, and at a time when no one knew any thing of the degenerations of organs, the question remains thus: — are these the limbs of leaves devoid of petioles, or petioles devoid of limbs?

I incline to the last opinion, for the following reasons: —1st. The analogy of these organs with leaves, where a limb and petiole are constantly recognised, is evident. If *Strelitzia juncea* has only petioles, it is difficult to believe that the pretended leaves of *Littæa* can be of another nature. If the sheath which supports the limbs of *Epidendrum* be a petiole, it is difficult to maintain that the sheath of other Orchideæ is not one also. If the sheath of the Gramineæ be a petiole, why are the sheathing leaves of neighbouring families anything else? 2d. In the two classes of Vasculares we know many examples of sheathing petioles, but none of sheathing limbs. All the limbs of leaves, whatever the disposition of their nerves, contract at the base, and present at this point a divergence of their fibres, more or less distinct; it is observed in the limbs of the Aroideæ, Potamogetons, Palms, &c. as in Dicotyledons: it is in this divergence that consists the idea of the limb and the spreading out of the fibres. But all these leaves spread out at their base as petioles, instead of contracting as limbs. 3d. Phyllodia, or petioles without limbs, in Dicotyledons, are terminated either by a spine, like that of Aloes, or by a tendril, as in *Flagellaria* and *Methonica*, or by a callosity, as in the Hyacinth, and a multitude of others. These different modes of termination, which indicate an abortion, are found under analogous circumstances in both classes. 4th. The study of Dicotyledons has proved that there exists a great number of examples of leaves without limbs, and, consequently, it may equally as well be admitted in Monocotyledons. This phenomenon is, in each class, more frequent in some families than in others.

I think then that in this class, as in the preceding, there exist:

1st. Leaves having a limb and petiole: such as, among Monocotyledons, *Sagittaria*, *Potamogeton natans*, *Hemerocallis*, Palms, the Gramineæ, &c.; and in Dicotyledons, the Pear, *Robinia*, &c.

2d. Leaves having only a foliaceous petiole, performing the office of a limb, as in the submerged Potamogetons, Hyacinth, Iris, &c., among Monocotyledons; the Acacias with phyllodia, *Bupleurum*, *Lathyrus Nissolia*, &c., among Dicotyledons.

3d. Leaves having a true limb devoid of petiole, as those of *Trilium*, *Paris*, *Lilium*, &c., among Monocotyledons; and all sessile leaves among Dicotyledons.

Let us observe, on concluding this Section, that the word "leaf" is taken, in works of descriptive Botany, sometimes for an entire leaf, composed of petiole and limb, which is the more regular and usual case; sometimes for a limb devoid of petiole, as is said of sessile leaves; sometimes for a foliaceous petiole without a limb, as in the family of the Liliaceæ, or in the Mimosas with phyllodia. We shall shortly see that this term of leaf is likewise often confounded with those of leaflet or segment.

Section III.

Of the Disposition of the Nerves in the Limb of the Leaf.

If the distinction which I have endeavoured to establish between the petiole and limb of leaves has been attentively followed, it will be seen that these two organs differ essentially in two respects. 1st. Petioles, whatever be their form or nature, are composed of parallel fibres; and if the parallelism is not exact, the fibres are generally more distant at the base, and nearer together above. 2d. Limbs present all the fibres or nerves diverging more or less at the base, whatever may be their ulterior direction: it is this mode of divergence of the fibres of the limb that we have now to examine.

Let us commence first by excluding from this examination a certain number of leaves, the nerves of which are so weak, so indistinct, or so completely buried in the cellular tissue, that their direction cannot be known with certainty: these are the leaves of fleshy or succulent plants, as those of the Ficoids, or the bases of petioles reduced to the state of membranous scales, as the scales which represent the leaves of *Asparagus* and *Ruscus*. The principles which I am about to set forth may doubtlessly be applied to them, but with such modifications and difficulties as would be injurious to the understanding of the general laws.

The fibres which were united together in the petiole, and proceeded there nearly parallel to each other, diverge, to form the limb, after two different principles: 1st. Some separate by forming, either with the base or with its prolongation, an angle, properly so called, and most frequently a right angle; we may call these ANGULINERVED leaves; 2d. The others separate by forming at the base, or its prolongation, a curve more or less extended: these may be named, by comparison, CURVINERVED leaves. The former are essentially the leaves of Dicotyledons; the latter, the true limbs of those of Monocotyledons.

Among angulinerved leaves, I have for a long time distinguished four dispositions of the nerves; viz.—

1st. PENNINERVED leaves (Pl. 10, fig. 3), or those in which the petiole is prolonged into a longitudinal nerve, which emits, from both sides, upon the same plane, lateral nerves; for example, the Chestnut. These lateral nerves are sometimes thick, at others very slender; sometimes far apart, at others near one another; sometimes simple, at others more or less ramified; sometimes perfectly straight, at others curved at their extremity, gradually following the border of the leaf, &c. They form at their origin, with the longitudinal nerve, an angle, usually acute, but the degree of which varies much. In certain leaves the angle is very acute, and the leaf is generally elongated. At other times they separate at a much less acute, or even at a right angle, and then the leaf is proportionally larger. Another difference influences much the form of penninerved leaves, viz.—the relative proportion of the lateral nerves. If the leaf has all of them short, but of the same length, its form is LINEAR; if those of the middle are longer than those of the base and apex, the form is generally ELLIPTIC, OVAL, or ORBICULAR; if the longest are found below the middle, the limb is OVATE; if they are above it, it is OBOVATE.

One of the remarkable cases among penninerved leaves is, that where the two lower nerves, although evidently springing from the middle one, are larger than all the following, and almost attain the size of those of the middle, these leaves are called Triplinerved; for example, *Helianthus tuberosus*. Sometimes the two lower nerves of each side are large, and near each other, and then the leaf is Quintuplinerved (for example, in several species of *Melastoma*), because it has five nerves near the base, viz.—two on each side, springing from the middle one.

This structure leads us by almost imperceptible degrees, to the second of the great classes of leaves.

2d. Leaves are said to be Palminerved (*i. e.* having the nerves disposed like the fingers, separate from each other), when several diverging nerves spring at the same time from the base of the limb: they are most frequently of an uneven number, the middle one being prolonged direct from the petiole. Sometimes as many as seven or nine nerves are counted; for example, in several Malvaceæ—*Malva Hennigii*, *M. Braziliensis*, &c., *Althæa*, &c. &c. Most frequently only five are found, as in the Vine; or three, as in the *Zizyphus*, and a number of other plants; but it is often difficult to distinguish accurately between quinquinerved and trinerved palmate leaves, and quintuplinerved or triplinerved ones. The only difference consists, in fact, in this—that in the latter the fibres remain a little longer connected with the central bundle, or the parenchyma is prolonged a little along the summit of the petioles. Equal numbers of nerves are much rarer than in the preceding, and probably are only owing to combinations of leaves, originally impari-pinnate. We can, at least as to the appearance, reckon among palminerved leaves with equal numbers of nerves, those of *Bauhinia*, where there are two; those of *Oxalis tetraphylla,* where there are four, &c. But we will revert to this subject after we have examined compound leaves.

If the position of a palmate leaf which corresponds to each partial nerve be examined, we shall see that this nerve emits lateral ones, in the manner of penninerved leaves, and all that we have said above is applicable to them; whence it results that a palminerved leaf may be considered as formed of as many penninerved leaflets, united at the base, as there are principal nerves; and it is particularly favourable to this opinion, that the families which have palminerved leaves present also compound ones, formed in an analogous manner; such as the Ampelideæ, Malvaceæ, &c. This opinion will be still better understood, when, on studying compound leaves, it is remarked that all leaflets, even those of palmate leaves, are penninerved.

The general form of palminerved leaves is essentially determined by the degree of divergence of the principal nerves, by their relative length, and by their number. When they are not numerous and but slightly diverging, the leaf may have a narrow and long form: it will, on the contrary, be wider or rounder as the nerves are more numerous and more diverging. The extreme case of this last combination is that which constitutes the third class of leaves—that of peltinerved ones.

3d. Leaves are said to be PELTINERVED, and the nerves PELTATE, when from the summit of the petiole there spring several nerves which radiate upon the same plane, which is not in the direction of the petiole, but forms with it an angle, often a right one, or nearly so, and the two external nerves are so near that the lateral limb of each is joined to the other. It results from this disposition, that in this kind of leaf the limb does not seem to be the prolongation of the petiole, but has the appearance of a disc placed upon the summit of it; it is this appearance, which, compared to a shield, has caused these leaves to be called peltinerved: such are those of the *Ricinus communis, Tropæolum majus,* &c. When all the nerves which radiate from the top of the petiole are equal in length, the leaf has nearly an orbicular form, and the angle of the limb with the petiole is almost a right one; when the angle is acute, the nerve, which, by its direction, is the prolongation of the petiole, lengthens more than the others, which, on both sides, diminish in length: the general form then is ovate, or even sometimes elongated. There are cases where the narrow part of the limb is so much contracted that peltate leaves are confounded with palmate ones; and species are found among the Menispermeæ, for example, the leaves of which assume almost indifferently these two forms. Thus all that I have said of palmate leaves may be applied to those which are only a modification.

4th. PEDALINERVED leaves differ much from all the preceding, in that the longitudinal nerve remains very short, sometimes nearly absent; but from both sides of it arise two strong lateral ones, which diverge upon the same plane, and, instead of ramifying equally on the two sides, present few or no lateral nerves on the outer side, whilst on the inner they give rise to very strong secondary ones, nearly parallel to each other. This singular disposition only exists in a small number of plants; and notwithstanding this circumstance, it is remarkable that these are the leaves where the distinction between angulinerved and curvinerved ones, or those of Dicotyledons and Monocotyledons is least decided. Among the first, pedalinerved leaves are found in the *Gincko, Helleborus fœtidus,* and some species of *Passiflora;* among the second, several are found in the Aroideæ; these have, it is true, a very decided tendency to have curved nerves, peculiar to the class of Monocotyledons, and they serve also to confirm this fundamental distinction.

We come thus to the second of the great divisions,—that of leaves with nerves curved at their base, or CURVINERVED ones. Among these we ought to distinguish two classes, viz. those with CONVERGING nerves, and those with DIVERGING ones.

In the first the nerves are sometimes curved throughout their whole length, which causes the limb to be oval or round, as in *Hemerocallis*, &c.; sometimes slightly curved at their base, and straight, parallel, or slightly converging at their apex, as is seen in the Gramineæ. In all those plants, which represent among phanerogamous Monocotyledons nearly what are the palminerved leaves among Dicotyledons, the nerves spring from the top of the petiole in great numbers, and are the closer to each other the nearer they are to the middle. Most frequently they are so close towards the centre that they perform the part of a longitudinal nerve. When the nerves which spring from the base are very near together, they are generally very small, and perfectly simple; when they are more distant they are also thicker, and tend a little to ramify laterally, as is seen in *Dioscorea*, *Smilax*, &c.

Diverging curvinerved leaves present precisely the opposite organization. The nerves united in the petiole form a very thick bundle, and the formation of the limb takes place by the lateral fibres of the petiole diverging, at a certain point, on both sides, under the form of little pinnate veins, which by their junction form an oval limb, with small, parallel, and simple nerves. In proportion as this separation of the lateral fibres takes place to form the limb, in proportion likewise the central bundle diminishes in thickness, until it finally disappears on reaching the apex: we see this in *Musa Paradisiaca*, *Strelitzia*, and several others.

The beautiful family of Palms presents the two dispositions peculiar to curvinerved leaves. Those, with leaves cut out so as to imitate palmate ones, belong to the division of converging curvinerved, and those the lobes of which resemble those of pinnate leaves are of the division of leaves with diverging nerves.

The distribution of the stomata in leaves is connected with that of the nerves. Among angulinerved leaves, the nerves of which ramify much, forming more or less irregular spaces, the stomata are scattered over the limb; on the contrary, in curvinerved ones, which have for the most part the lateral nerves simple, or but little ramified, the stomata are arranged in longitudinal rows between each little nerve.

The general form of the limb, which is so frequently mentioned in botanical works, results from the disposition of the nerves, and its anatomical importance is consequently much less than that of the cause which produces it. There may be, and there are in fact, ovate leaves formed by all the systems of nervation which I have mentioned; consequently it is not sufficient in describing a leaf to mention its form, but its system of nervation must especially and most expressly be described.

From this Section it may be seen that, although there still remain some exceptions (especially among pedalinerved leaves), we can, however, easily distinguish the structure of the limb of the leaf in the two great classes of Phanerogamia: Dicotyledons are known by their nerves on separating forming angles, whilst in Monocotyledons they form curves; the former are classed into penninerved, palminerved, and pedalinerved leaves, but their lateral nerves are always ramified after the system of pinnate nerves; the latter are divided into leaves with curved nerves, diverging or converging; lastly, pedalinerved leaves are found, the principal nerves of which form angles and other curves, and notwithstanding the resemblance they bear to each other, the former belong to Dicotyledons, the latter to Monocotyledons.

Let us now examine how we may deduce from these primitive dispositions the theory of the leaves.

Section IV.

Of Lobed Leaves.

It is particularly in all that relates to the divisions of leaves, that the method of considering the limb as an entire surface, which, in certain cases, would present divisions, has been pushed to the greatest degree; but when these pretended causes came to be examined, it was impossible to elucidate them. It is, in fact, setting out with a wrong idea: leaves are not entire surfaces which are cut; they are portions of limbs, which in uniting, or remaining united in different degrees, constitute sometimes projecting or retreating angles, sometimes entire surfaces. All the terms intended to indicate the different degrees of division of leaves have been believed, and universally admitted, under the sway of the first hypothesis; I am about to give the details of the second, and, not to innovate too much, I will adopt the old terms. If some do not appear either sufficiently applicable or exact, it is in order to spare a superabundant multiplication of words that I employ them, and I must not be rendered responsible if this collection of terms, believed in another sense, does not answer exactly to that which I propose.

In order to give a true idea of the lobes of leaves, it is sufficient to set out with the same idea of the foliaceous structure: a long or short petiole is formed of a bundle of fibres; these, diverging after two different systems, separate from one another and form the nerves, each of which ramifies after a given system; and thus it proceeds until all the fibres of the bundle and all the vessels of the fibres are isolated. Each fibre being formed of vessels and cellular tissue intermixed, the latter is developed when the separation of the vessels leaves room for it, and then it tends to fill up the intervals; these being in this manner filled with cellular tissue, the whole appears entire; but it may happen that the vessels diverge too much in proportion to the increase of the cellular tissue, so that it cannot occupy all the interval which separates them, and then it fills up only a part of the angle which they form between them; and from the cellular tissue not filling up the entire interval, it results that there is a retreating angle, which is called a SINUS.

When this phenomenon takes place in the last ramifications only of the nerves, small projecting angles are formed, which are called TEETH, or indentations, and little sinuses, which have not received any particular name. If the teeth are sharp, the margin is said to be SERRATED. If they are very obtuse, it is CRENATED.

All that I have said of the vessels or fibrils of a fibre may take place from analogous causes between the lateral nerves of a pinnated leaf. Let us suppose that these nerves are very near each other; the parenchyma formed by their ramifications may be developed so as to reach that which proceeds from a neighbouring nerve, and in this case it unites with it before the period of development which is visible to our eyes; it is thus that in penninerved leaves the limb is entire, if the lateral parenchyma of all the lateral nerves remains united as far as the top of these nerves; but if the nerves are too distant from each other in proportion to the possible development of the parenchyma, then the portions formed by the development of the secondary nerves, or the LOBES, as they are called, in a general manner, remain united,—for example, about half way; the projecting parts take the name of DIVISIONS, and the sinuses that of FISSURES; and to express at the same time that the leaf has pinnate nerves, and that its lateral lobes are united about half way, it is said to be PINNATIFID.

Let us suppose either a greater separation of the secondary nerves, or a parenchyma less disposed to be developed, the lobes may be only united at their base; they are then called PARTITIONS, and the leaf is said to be PINNATIPARTITE; lastly, the nerves may be still more separated, or the parenchyma still less developed, the lobes will be totally independent and not united together; then they take the name of SEGMENTS, and the leaf is said to be PINNATISECTED. It sometimes happens that, at the base of the petiole, the lobes are completely isolated, and more or less united above; this inequality is expressed by saying that the leaf is LYRATE: if one wishes to say that a penninerved leaf has its lateral nerves separate, except at the apex, without expressing where the junction is, the leaf is said to be PINNATILOBED.

We easily understand that all that I have said of the secondary nerves may be said of the tertiary, or, in other terms, each of the projecting lobes may be pinnatifid, pinnatipartite, or pinnatisected: this is expressed by saying BIPINNATIFID, &c.; the lobules themselves may present the same division, and the leaf is then said to be Tripinnatifid, &c.; but beyond a double division it is rarely that the trouble is taken to examine the regular system, and under the names of Multifid, Laciniated, Decompound, or Dissected, are confounded all leaves with numerous and indefinitely divided lobes.

The same theory may be applied to all palminerved or peltinerved leaves, with this single difference, that one applies to the principal nerves of these leaves all that is said of the secondary nerves of penninerved ones. Thus, in these palmi- or peltinerved leaves, the lobes are the expansions of each of the nerves which arise from the top of the petiole, and the leaf is said to be Palmatifid or Peltifid, when the lobes are united half way; Palmatipartite or Peltipartite, when they are only so near the base; Palmatisected or Pedatisected, when they are not at all.

As for pedalinerved leaves, the secondary nerves are those which, as in penninerved ones, give origin to lobes more or less united together.

Thus, in all the classes of leaves with ramifying or angular nerves, it is the unequal uniting together of the lobes which causes the divisions; and the union of the extremities of the fibrils, which, by its inequality, produces the teeth; and it is so true that these facts ought to be referred to the more or less considerable development of the parenchyma, that in several kinds of plants the divisions are seen to vary in depth according to the varied action of the causes which make the fibres elongate or the parenchyma to be developed; thus, a nourishment very watery, and but little endowed with nutritive matter, causes the fibres to elongate, without the parenchyma being sufficiently developed, as we see in several aquatic plants, and especially in *Ranunculus aquatilis*. A small quantity of nourishment renders the leaves more divided, and a very substantial aliment gives the parenchyma sufficient development to fill up the intervals of the lobes; thus, most plants with divided leaves tend to have them more entire in rich soil or in gardens.

Among leaves with simple or curved nerves, divisions are much more rare; and if the Aroideæ be excepted, the leaves of which approach the preceding class, it may be said that they all have the limb entire.

The Palms seem to form, in this respect, a great exception, but the nature of their leaves presents a character which is peculiar to them: they often appear divided either in the manner of pinnatisected leaves, or resembling palmatisected ones; but they are really torn into strips, which follow the direction of the lateral fibres. This tearing, natural and regular, is very evident in following the Palms from their young state; for then their leaves are entire, and the tearing is gradually seen to take place, commencing from above, and extending to the principal bundle of fibres.

If the natural tearing of the leaves of Palms appears to me to be a fact beyond a doubt, the cause of this phenomenon, or the mechanism which produces this rupture, is very difficult to be assigned. We see that the lateral fibres converge in their young state towards the apex of the leaf; and as they diverge a little towards the base, it is likely that, according to the degree of divergence and the rapidity of growth, there arrives a period, in each leaf, when the fibres, developing by the base, force their upper parts to separate, so as to form the strips of which I have spoken: these strips are distributed to the top of the petiole, when the lateral nerves spring from it; and on both sides of a common bundle, when it exists throughout their whole length. The depth of the strips varies like those of ordinary lobes.

In order to indicate these forms in a manner analogous to the admitted terms, and at the same time to show that there exists a difference, I think that it will be right to reserve for the leaves of Palms the terms PINNATIFORM and PALMATIFORM, and for their pretended lobes the name of STRIPS, which exactly expresses their nature; thus the leaves of Palms alone, in the vegetable kingdom, answer to the idea which was formed, before examination, of the divisions of leaves: these are really entire leaves which are divided, whilst all the others are portions, unequally joined together. This tearing takes place after expansion, as in young Palms, or before it, as is most frequently the case in old ones.

All that we have hitherto explained relative to the lobes of leaves, is applicable to the lateral ones of those with pinnate or penniform nerves, and to the terminal ones of those with palmate, palmiform, peltate or pedate nerves; but it now remains for us to speak of the emarginations which are so frequently observed, either at the base or apex of foliaceous surfaces.

The emarginations of the base can by no means be referred to the preceding theory, and result from simple causes. In penninerved leaves it often happens that the lower lateral nerves are larger and more developed than the others; and their secondary ones are developed more on the external side, where they find no obstacle, than on the inner one, where they meet with those which spring from the neighbouring nerve. It results from the development of these secondary nerves that the limb is prolonged beyond its origin; or in other terms, that the base of this limb has an emarginated appearance. When the auricles thus produced are round, the limb is said to be CORDATE; when they are pointed and directed parallel with the centre nerve, it is SAGITTATE; when they are diverging, and almost perpendicular upon the inner side, it is Hastate.

Leaves with curved and simple nerves cannot be emarginated at the base; they are so but seldom, and then very slightly. When this form is presented, it is owing to the peculiar curve of the nerves which form the limb, as is seen in some species of *Hemerocallis* and *Musa*.

The emarginations of the apex of leaves, leaflets, or lobes with pinnate nerves, result from two causes:—1st, From the lateral nerves of the apex being directed forwards, and prolonged a little more than the middle one: this takes place in most leaves emarginated at the apex. 2d, From the lobes or leaflets which arise from the extremity of the two sides of a middle nerve being incompletely united, and leaving between them a sharp and often very distinct sinus; it is thus that the pretended simple leaves of *Bauhinia* are emarginated, because the junction of the leaflets does not take place as far as the apex. (Pl. 11, fig. 1.)

Lastly, in some palminerved leaves, emarginated limbs are found; this takes place when the middle nerve is very short and the two lateral ones very long, as is seen, for example, in several species of *Passiflora*. (Pl. 11, fig. 2.)

One of the most curious phenomena which the organization of leaves presents, is the presence of holes or gaps, which are naturally formed in the limb of *Dracontium pertusum*. These holes, although sufficiently frequent to have given the plant its specific name, are not however regular: when the plant is nourished very abundantly, it has few or none, and they are seen to increase in number in those grown in a poor soil; these holes are of an oblong form, and placed between the principal nerves. All those who understand the manner in which the lobes of simple leaves, or the partial limbs of compound ones, are united so as to form entire limbs, will readily admit, I think, that these holes are owing to portions of limbs being incompletely united by some defect of development of cellular tissue. They must not be confounded with the round holes which are observed in several kinds of *Ulva*, which result from the destruction of tissue after fructification, and to which we shall hereafter revert.

Pothos crassinervia also presents a phenomenon which cannot be referred to any class of known facts: when the plant is old, the leaves have kinds of straight callous lines, parallel to the thick sides, and cutting all the veins transversely; they open below into a kind of slit, closed on the upper side, and bordered by two little limbs.

The undulations of foliaceous surfaces are produced by a contrary cause to that which, in the ordinary state, produces the lobes; that is to say, because the cellular tissue is developed between the fibres in greater quantity than can be contained in the plane which separates them: then it forms more parenchyma than the space can hold, and the surface becomes undulated; we see this, for example, in a variety of *Scolopendrium officinale*, &c. This effect frequently results from a superabundance of nutriment.

Section V.

Of Compound Leaves.

We have hitherto spoken of leaves as if all their parts were always continuous; but some are often met with, which, in certain portions of their extent, present articulations, so that each of these portions can be detached, at least when mature. The name of SIMPLE is given to all those the parts of which are continuous, whether they are entire, or divided in the highest degree; and in contradistinction, all those are called COMPOUND, which present joints which can be separated at some period of their existence.

The distinction between compound leaves and those with separate segments, is often difficult in practice, especially when they are young. The names of *simple* and *compound*, although convenient in practice, are not perhaps correct in reality; for one might say, with as much reason, that the leaves called simple are formed by the constant uniting together of leaflets into a single limb. The example of the leaves of *Gleditsia*, and others, which often have the leaflets united, might authorize this manner of considering it.

In leaves said to be compound, the general petiole which bears all the joints receives the name of the COMMON PETIOLE, and each joint that of LEAFLET, when it has the nature of a foliaceous limb. When the leaflets are themselves provided with a proper petiole, this receives the name of PETIOLULE; and if upon the common petiole others are found which are furnished with an articulation at the base, and bear leaflets, the name of PARTIAL PETIOLES is given.

Let us observe, at the commencement, that compound leaves are only found in the angulinerved class, or, what is nearly the same thing, among Dicotyledons. All the leaves of the other classes are simple, even when they resemble in their divisions compound ones,—as, for example, in the Ferns.

In order to give a just idea of Compound Leaves, we must return to what has been said above of the distribution of the nerves, and the formation of the lobes.

Let us take, in particular, the structure of leaves said to be pinnatisected, palmatisected, or peltisected; in these the segments have their limb distinct; but they are attached to the central nerve, or to the top of the petiole, by a nerve which is a division of the petiolary bundle, and continuous with it. Let us suppose now that instead of this continuity, the segment is attached to the petiolary bundle by a true articulation, and we shall have transformed, in thought, this segment into a leaflet, and the simple leaf into a compound one. This difference, although constant in the same species and in certain families, is so slight that it is often difficult to affirm if such partial limb be attached to its base by continuity or articulation; or, in other terms, whether it be a segment or leaflet, and whether the whole be a simple or compound leaf: this difficulty is especially experienced when the leaves are young; but when they approach the period of their fall the articulations are easily recognised, as they then have a tendency to disarticulate. We are also guided by analogy in this respect, as to foreign plants, of which we may only be able to see dried specimens; for there are some families where compound leaves are frequently found, and others where they never are.

Compound leaves, classed according to the distribution of the nerves, present corresponding divisions to simple ones: thus, they are said to be Pinnate or Winged when the leaflets are distributed on both sides of a common petiole, like the nerves of penninerved leaves—for example, in *Robinia*, *Astragalus*, &c.;—Palmate, when their leaflets diverge from the top of a common petiole, and in the same direction with it, like the nerves of palminerved leaves—for example, in the Lupine, Horse-chestnut, &c.;—Peltate, when their leaflets radiate from the top of a common petiole, but on a different plane, as the nerves of peltinerved leaves—for example, in *Sterculia fœtida*;—PEDATE, when their leaflets arise from the inner border of two principal nerves which diverge from the top of a common petiole ; but it is doubtful if true pedate leaves exist, and the small number to which this name has been given, appear to be simple pedatisected ones.

When the partial leaflets are distributed either along a common petiole, or at its extremity, after one of the systems which I have pointed out, and when they themselves bear leaflets distributed according to the same system, this disposition is easily and clearly expressed by saying that the leaf is BIPINNATE (Pl. 7, fig. 2, 3), or BIPALMATE (Pl. 11, fig. 3); and we should say, in the same manner, that it is BIPELTATE or BIPEDATE, if either of them happen to be found, which is not yet the case. We say, after the same principle, that the leaf is TRIPALMATE, &c.

When it is wished to express the number of the leaflets, it is stated by a paraphrase, or by the terms UNIFOLIATE, BIFOLIATE, and MULTIFOLIATE. This is very important in palmate or peltate leaves. Nevertheless, botanists often manifest a want of precision in this respect, and here and there employ the term of leaves instead of leaflets, or even of segments; thus, *Anthyllis tetraphylla* ought to have been called *A. quadrifoliata; Marsilea quadrifolia* is, truly, *M. quadrisecta; Sophora bifolia* and *Cassia diphylla* ought to have been named *bifoliolata*, &c.

As for pinnate leaves, the leaflets are most frequently opposite one another, and then they are counted by PAIRS *(jugum)*; thus, one says of a pinnate leaf, that it has one pair *(unijugum)*, or two pair, &c. When the leaflets are alternate, we can also, in most cases, recognise the primitive pairs, and continue to say that they have one, two, three, &c. pairs, although this term may then be hardly correct; but there are species where the leaflets are so evidently alternate, that we do not venture to employ this term, but are contented then to say that they are alternate, and mention their number.

In all these classes of compound leaves, the leaflet which is placed at the direct prolongation of the petiole bears the name of the TERMINAL LEAFLET, because it terminates the common petiole; or of the MIDDLE, or more conveniently the ODD LEAFLET, because there are an equal number on each side of it. It frequently happens that this terminal leaflet remains alone, all the others being wanting: this takes place in the Orange, and several Leguminosæ. At first sight these leaves seem to be simple, but they are known by their leaflet, or that which appears to be the limb of a simple leaf, being articulated with the top of the petiole: we are also guided in this respect by analogy; thus, all the family of the Aurantiaceæ have compound leaves; and the genus *Citrus*, to which the Orange belongs, comes under this rule, since the articulation can be seen which separates the terminal leaflet from the bordered petiole. It is also by analogy, and by analogy alone, that we can know whether an unifoliolate leaf belongs, in its primitive plan, to pinnate or palmate leaves; thus, it is likely that the Orange is a pinnate leaf reduced to the odd leaflet, and that the *Sarcophyllum* (Pl. 10, fig. 4) is a palmate leaf reduced to the middle leaflet, for all the analogous species are constituted upon this type.

It is very frequently remarked that in the same species the leaves at the base of the branches have several pairs of leaflets besides the middle one, whilst in those which are nearer the top the number is so diminished that the upper leaves are sometimes reduced to the terminal leaflet. There is in like manner a certain number of plants which seem to have simple leaves, but which may be considered as having compound ones reduced to a single leaflet; this evidently happens when the common petiole is visible, as in the Orange, but it does not the less take place when it is absent or very short. This evidently appears to me to be the case in the species of *Genista* and *Cytisus*, said to have simple leaves.

This shortness of the common petiole is also remarkable in another respect: when the leaflets to the number of three, five, or seven, &c. arise from an extremely short petiole, they then seem to do so in bundles; we see this in *Aspalathus*. In comparing together the species of this genus, we find some which have the leaves unequally pinnate, and a very distinct petiole; in others it hardly exists, the number of leaflets remaining the same.

When the leaflets are three in number, it is often difficult to decide whether the leaf forms part of the system of pinnate or palmate leaves; and most authors have left the question undecided, and have classed them without examination among the palmate ones. The only rule which I know to remove this doubt is this:— When the three leaflets have their articulation situated exactly at the top of the petiole, the leaf ought to be considered palmate; for example, *Cytisus*, and most species of *Trifolium*. When the common petiole is prolonged beyond the two lateral leaflets, and the articulation of the terminal one is more or less distant from the other two, as in *Medicago*, *Desmodium*, &c. the leaf ought then to be considered as a pinnate one, with only two pair of lateral leaflets.

There is a numerous class of pinnate leaves which have an even number of leaflets—that is to say, in which the terminal one is wanting; they are said to be ABRUPTLY PINNATE *(pari seu abruptè pinnata)*; they may have, like the preceding, the lateral leaflets either opposite, as is most frequently the case, or alternate, which has sometimes caused it to be falsely thought that the last lateral one is an unequal one; but it is always distinguished from the true terminal one in its not being at the top of the common petiole, which is prolonged a little beyond it.

The petiole may be prolonged either into a branching tendril, as in *Vicia*, or into a simple process, as in *Orobus*, or in spines, as in *Astragalus*, or (what is more singular, and has not, I believe, been remarked,) in a true foliaceous limb; this takes place in the Walnut, its leaf is pinnate, with two or three pairs of lateral leaflets articulated with the petiole, and that which has the appearance of the terminal leaflet is a foliaceous expansion of the petiole into a true penninerved limb, continuous with the petiole, and not articulated. This phenomenon establishes a new connexion between compound and simple leaves.

A peculiar case of this class of leaves is where the extremity of the petiole, which bears the lateral leaflets, is prolonged into a foliaceous cup, hollow and funnel-shaped; I have accidentally observed this in the Pea and *Gleditsia*.

We have said that most abruptly pinnate leaves have the leaflets opposite in pairs. The number of these pairs is sometimes very great, sometimes very small; sometimes there is but one, as in *Acacia diphylla*. When the petiole is prolonged in any form beyond the origin of the leaflets, there is no doubt that the leaf ought to be classed among pinnate ones; but when it is not prolonged it may be classed indifferently, either as a pinnate leaf with one pair of leaflets, or as a palmate one with two leaflets. The analogy of families where this organization takes place makes me think that, even in this case, leaves with two leaflets ought always to be considered as pinnate ones, reduced to a single pair, without a terminal one, or a petiolary prolongation; thus the genera *Hymenæa* and *Bauhinia* deserve the name which Linnæus has given them.*

It is a rule which appears to me without any real exceptions, although there may be apparent ones, that the leaflets of compound leaves have all the nerves pinnate. The fact is so evident, for the most part, that it is sufficient to express it for any naturalist not to doubt that it is at least generally the case; the apparent exceptions are,—that sometimes the two lateral and lower nerves may be so large and so near the base as to resemble palmate nerves, and that the lateral distinct leaflets may be united with the terminal one, so as to form together a leaf with several distinct nerves; this phenomenon merits some details.

Let us suppose a pinnate leaf, the two superior lateral leaflets of which arise so near the terminal one as to be united with it, and we shall have, as in several Rosaceæ, and some Leguminosæ, a winged leaf terminated by a limb, with three palmate nerves, and frequently with three lobes. As the same thing may take place in a palmate leaf, with three or five leaflets, it is transformed into a leaf, the limb of which will have three or five nerves, and probably three or five lobes. If it take place in abruptly pinnate leaves, the junction is a little more difficult, because the distance between the terminal leaflets is rather greater; but it also takes place sometimes: thus, on comparing together the different species of *Bauhinia*, it is difficult not to be persuaded that their limb is formed by the natural junction of the inner borders of the two lateral leaflets;

* *Hymenæa* signifies that the leaflets are, as it were, married, and *Bauhinia* makes allusion to the two brothers Bauhin, celebrated botanists.

and the little process which is observed in the sinus, which results from the incomplete uniting together of the leaflets, is probably the apex of the common petiole, (Pl. 11, fig. 1.)

A very remarkable circumstance of this union of the leaflets is, that every time it takes place the leaflets thus united and transformed into a single limb have no articulations; we see this in *Bauhinia*. This circumstance tends also to connect intimately compound with simple leaves.

Thus a compound leaf may appear simple, either because all the lateral leaflets are abortive, or because the common petiole is so short that the leaflets appear to be leaves springing in a bundle from the stem, or because the leaflets are united into one limb.

But are the leaves which are called simple any thing more than compound ones, with united leaflets? One might be inclined to believe that this manner of expression approaches the truth nearer than the usual one; but we know that it is hazardous, and luckily useless, to establish an absolute opinion in this respect, provided that we see that the thing is possible, and that it surely takes place in several cases. This theory is especially applicable to palminerved or peltinerved leaves, which only seem formed by the junction of several palmate or peltate leaflets; but as all these leaflets have the limb penninerved, this remarkable law results,—that all the leaves of Dicotyledons may one day be considered as pinnate limbs, differently joined together.

Section VI.

Of the Cavities of Leaves.

Most leaves are flat or thick, and in each case their internal surface does not present any closed cavity, and even their surface has none which is open externally; but there are some leaves which, from different causes, form exceptions to those two general laws.

In order to commence with the more simple cases, which tend to render the others clear, we see that several plants, which have the petiole large and foliaceous, have this organ curved in such a manner as to form a kind of longitudinal tube, with a fissure on its inner surface; sometimes this tube sheathes the stem, as in the Gramineæ, or certain Amomeæ, where it bears the name of Sheath; sometimes it diverges from the stem at its origin, and has the appearance of an empty tube, split upon one side: this takes place in *Sarracenia*, where it may be considered as a tube formed either of a foliaceous petiole, or by the limb of the leaf; it can contain but little or no liquid on account of the lateral fissure. In some plants, with palminerved leaves, the nerves are numerous, very near each other at the base, and disposed in such a manner that the limb forms a horn-shaped reversed cone, as is seen in *Pelargonium cucullatum*. Some other plants present accidentally an ànalogous disposition, but with the two borders of the horn united together, so as to form an entire horn, or reversed cone; this accident is not rare in the Lime (*Tilia*).

It happens in some cases that the top of a common petiole, instead of being prolonged into a tendril, spreads out into a kind of hollow foliaceous disc, which forms a little cup; this is found from time to time in *Vicia*. I have seen a sub-variety of Cabbage, the large nerves of which were prolonged beyond the limb, and were spread out into well developed cups.

The *Nepenthes* presents an organization analogous to the two preceding, but more remarkable than either; its petiole is sheathing at the base, afterwards it contracts into a nearly semi-cylindrical body, then it spreads out into a foliaceous expansion, which may be considered either as the border of the petiole, or as the limb of the leaf; whichever it be, the petiole (if it be a border) or the middle nerve (if it be a limb) is prolonged beyond this foliaceous expansion, under the appearance of a short and thick tendril, which spreads out at its apex into a long hollow cup, closed at the sides, and with a nearly circular opening at its extremity; on the side of this orifice, which corresponds to the base of the petiole, is a flat orbicular disc, capable of closing the cup when it is depressed, and of opening it when raised up; the interior of the cup secretes, it is said, a peculiar liquid, and the orifice is a hard rim of the inner surface.

I am inclined to believe that the disc forming the lid is the true limb of the leaf, and all the rest of the apparatus is a dilatation of the petiole. I ought to confess, however, that until something intermediate has been discovered between this extraordinary structure and the ordinary form of leaves, it will be difficult to form very decided opinions in this respect.

The cups of *Cephalotus follicularis* are perhaps more extraordinary than the preceding, and more difficult to refer to any known form. This plant, from New Holland, presents, in fact, two kinds of leaves, the one flat, oval-oblong, and which do not present any thing remarkable; the others, situated a little below the preceding, are composed of a petiole, dilated at the apex into two lips, the lower large and very concave, open above by a circular orifice, which is hard and provided with three nerves or longitudinal wings on its outer border; the upper lip is smaller, flat, and acts as a cover to the cup, which is often half filled with a slightly sweetish liquid; but I do not know if it is secreted by the plant, or produced by the entrance of the rain.

Hitherto we have seen examples of cavities opening externally, but there are other leaves which present them entirely closed; such are, for example, the cylindrical and hollow leaves of several species of *Allium*, and of some kinds of *Ornithogalum*. These leaves are traversed throughout their whole length by a remarkable cavity: it may be believed that this is either a true hollow, produced by the tearing of the internal cellular tissue, or that it is a tube formed by a petiole dilated into a leaf, folded into a tube, and having its edges and apex united. Thus, in the same manner as the sheath of the Cyperaceæ seems analogous to that of the Gramineæ, except that it has its edges united,—in the same way it may be said that the fistular leaves of *Allium* differ from those of *Sarracenia* only by this uniting together of the edges. The structure of the leaves of *Iris* tends to confirm this last hypothesis.

Finally, there are some leaves which present several cavities, which there are some reasons for regarding as simple gaps: such are the quadrilocular leaves of *Lobelia Dortmanna*, and of *Isoetes palustris*.

Section VII.

Of the Disposition of the Leaves upon the Stem.

The disposition of the leaves upon the stem may be considered either with regard to the parts of the stem itself, or as to their succession in the duration of vegetation, or especially in reference to the comparison of the leaves with one another.

In the first point of view, which is the least important, we distinguish them as Radical, Caulinary, Ramal, and Floral. These terms, although easily comprehended of themselves, require some explanation. All leaves spring from the stem or the branches, and all ought, consequently, to be classed under the terms *cauline* and *ramal:* the two others also are only abbreviations to designate a complex idea; those leaves are called *radical* which arise so near the root that they seem to proceed from it, and not from the stem; such are those of the Dandelion or the Hyacinth. There are plants, such as those I have mentioned, and also *Isoetes*, the stems of which are so short that during the whole period of their existence they have only radical leaves. There are others, principally biennials, the stem of which remains very short the first year, so that during this period all the leaves are radical; the second year the stem elongates, and is furnished with caulinary and ramal leaves, the radical ones perishing: we see this in most species of *Œnothera* and *Verbascum*. Lastly, there are others, the stem of which is elongated and provided with leaves, and bears also at the base other leaves, in size and form so different from the ordinary ones that they are obliged to be described separately, under the name of radical leaves; such are those of

Anemone, &c.: these radical ones are usually larger and more cut than the others.

As for *floral* leaves, all those are designated by this name, which arise in the neighbourhood of the flowers: we shall have occasion to revert in detail to their history when we speak of the Inflorescence; and we shall only remark here, that they often differ from the ordinary ones in their form, dimensions, colour, and even in their position.

Caulinary Leaves, considered with regard to their succession at different intervals, are named SEMINAL, PRIMORDIAL, or ORDINARY. The SEMINAL ones are the cotyledons of the seed developed into leaves, the first which appear at germination; the PRIMORDIAL are those which immediately succeed the seminal: these two kinds of leaves, which are thrown off soon after their development, differ most frequently from all the following in important characters; they require to be specially mentioned, and we will examine them in the course of the article upon the Seed. I am also obliged to state here, that the description of the foliage of a plant means usually the ordinary caulinary and ramal leaves, and excludes all others: this is why Bonnet has given them the name of CHARACTERISTIC leaves.

The position of leaves with reference to each other, is much more important to study than any of the preceding modes of considering them, and it is intimately connected with the general symmetry of plants. Charles Bonnet was one of the first who called the attention of naturalists to this phenomenon, which he has especially considered physiologically, but which is not the less worthy of being studied in an organographical point of view.

We may recognise two great classes in the disposition of leaves:—The first is that of leaves placed, to the number of two or more, upon the same horizontal plane around the stem;—the second comprehends those which are always presented solitary on a horizontal section.

When more than one leaf is found upon the same plane, they are said to be OPPOSITE when there are two facing each other, and VERTICILLATE when there are several. It is customary to join to these two fundamental dispositions, those of GEMMINATE leaves; that is to say, those which arise side by side; but they are always a degeneration from some other primordial disposition: thus, sometimes they are really alternate, springing very near together, as in *Solanum;* sometimes they are verticillo-ternate leaves, one of which is accidentally wanting; sometimes portions of compound leaves, which are taken for entire ones, &c. Of leaves which spring upon the same horizontal plane, the opposite and verticillate only can be regarded as the essential dispositions. These two arrangements might be reduced to only one, for opposite leaves are, in reality, but verticils with two leaves.

It is an universal law in Organography, and which applies very particularly to this case, that the greater the number of parts, the less regular they are: thus, verticils with two leaves are the most constant of all; those with three, four, five, &c. are successively less so. Now and then we find verticils of two leaves which take three—as, for example, *Lysimachia vulgaris;* or those with three which take two, or four, &c. But when the verticils of ten leaves are examined, we frequently see them vary two or four above or below their usual number—for example, in *Galium.* These variations take place, either in an individual of the same species, or in the same individual at different ages and different periods of its existence.

Opposite leaves are almost always disposed in pairs, in such a manner that those of the second pair cut those of the first at a right angle, those of the third cutting those of the second at a right angle, and springing consequently immediately above those of the first; and so on in the same manner : this disposition is very evident in plants with a square stem, as the Labiatæ; and also in those with a cylindrical one, as the Lilac, for example. I know but one exception to this law,—it is *Globulea obvallata*, the opposite leaves of which are disposed in spiral pairs; that is to say, the second pair only cuts the first at an acute angle; the third cuts the second at the same angle; and it is only the sixth or seventh which comes immediately over the first, so that each system is composed of six or seven pairs spirally arranged. *Ajuga Genevensis*, according to the observation of Rœper, presents something analogous in the lower part of the stem.

As for verticillate leaves, the number of which is regular, each leaf of a verticil arises in the place which corresponds to the interval between two leaves of the lower verticil; whence it results that the leaves of the third correspond to those of the first, those of the fourth to those of the second, &c. &c. : this is a corresponding law to that of opposite leaves; but it is observed with less accuracy, because the symmetrical disposition is deranged as often as the number of the leaves of the neighbouring verticils is found to vary, which is so much the more frequent the greater the number is.

The constancy of the opposite or verticillate position of leaves is sometimes very great, sometimes very slight, according to anatomical circumstances; thus, this position is exactly followed — 1st, when the leaves are united together externally by their base, which happens in those said to be CONNATE; — 2d, when a kind of plexus of vessels, or a transverse portion, unites them together, as in the Labiatæ;—3d, when the stem presents distinct sides, the number of which corresponds to that of the leaves; such are the tetragonal branches of *Lagerstrœmia*. When either of these three circumstances does not exist, the opposite or verticillate position often suffers exceptions, especially in the neighbourhood of flowers and at the origin of the branches.

When the leaves are solitary on the same horizontal plane, they are usually designated in botanical books under the name of SCATTERED leaves, a very incorrect term, for they are primitively an order quite as regular as the preceding; or of ALTERNATE ones, an equally incorrect term, since it designates a peculiar case of the class, and that too which is the least frequent.

We may distinguish in this class three principal dispositions. 1st. Leaves are said to be ALTERNATE, in the strict sense of the word, when they are disposed on both sides of the branches in such a manner that the third is found over the first, the fourth over the second, &c.: among these alternate leaves we may distinguish, under the name of DISTICHOUS, those which are very near together, and in two distinct rows. 2d. Leaves are said to be QUINCUNX when they are arranged in a simple spire, formed of five leaves, so that the sixth is immediately over the first, the seventh over the second, &c.; this is a case of the most frequent occurrence—as, for example, in the Pear, &c. 3d. The name of SPIRALLY ARRANGED leaves is reserved for all those which have the spire formed of more than five leaves; and here we may reasonably distinguish the triple spires, such as *Pandanus* or *Dracæna*, in which each of the three spires which surround the stem proceeds parallelly, and is composed of from fifteen to twenty leaves;—quintuple, sextuple, &c., such as are found in different species of *Pinus*, *Euphorbium*, &c. I have even found octuple spires; such are the floral leaves, and consequently the flowers of some Aloes. I have counted thirteen parallel spires in the flowers of the male catkins of the Cedar of Lebanon.

In all these cases of multiple spires, they follow their course around the stem, parallel to one another. Their direction is sometimes from right to left, sometimes the contrary way in different species, and sometimes it presents variations in the same species. Thus Bonnet has counted seventy-five examples of Chicory *(Chicorium Intybus)* where the spire went in the first direction, forty-eight where it was in the second, and one in which both were united.

Plants which have the leaves disposed in many spires, are almost always species with long narrow leaves, such as *Pinus*, *Euphorbium*, &c. But the other dispositions have not, in general, any connexion either with the size or the form of the leaves. We can only say, that when they are large they are generally more distant, and the pairs, verticils, or spires, are nearer one another when the leaves are small.

All this distribution of the leaves is connected with the functions of these organs. They are destined to decompose carbonic acid gas, and to evaporate the superabundant water; and physiology informs us that these two functions are caused almost exclusively by the action of solar light. In order that this action may be properly performed, it is necessary either that the leaves be far apart from each other, or that with a given distance they cover one another as little as possible. In fact, we have seen that in all the different systems of the position of leaves, it results that those which arise immediately above the others never exactly cover them. In the least favourable cases, the third covers the first, and the fourth the second; in several others, it is the sixteenth, and sometimes the fifteenth or twentieth, which covers the first. Thus, in combining these dispositions either with the distance of the systems and their parts, or with the size of the leaves, which go on diminishing from the base upwards, we come to understand how all leaves enjoy the action of the solar light.

All these dispositions can, as we have seen, be reduced to two classes; viz.—1st, Verticillate leaves, which, when the verticil is reduced to its minimum, become Opposite;—2d, Spirally arranged leaves, which, when the spire is reduced to its minimum, become Alternate.

These two fundamental dispositions can be transformed from one into the other. In fact, when the leaves of a verticil are not joined together at their base, and as the stem which bears them gradually elongates, but following a spiral direction, which is very frequent, each leaf is found placed a little above the preceding one, and the leaves, instead of being verticillate or opposite, are spiral or alternate. When the first development of Dicotyledons is observed, we clearly see that this takes place: the first, or seminal leaves, are always regularly opposite or verticillate, and the following sometimes strictly preserve their original position, as in the Caryophylleæ, Labiatæ, Rubiaceæ, &c.: sometimes they gradually separate; thus, several plants, the adult leaves of which are spirally arranged, have the primordial ones opposite,* as is seen in several Leguminosæ, Compositæ, &c.

The contrary takes place, although more seldom, in Monocotyledons; their seminal or primordial leaves are always alternate or spiral. But it sometimes happens

* Cassini says that he has observed that those Dicotyledons which have the leaves spirally arranged, have their cotyledons clearly approaching each other on one side of the stem, whilst when they are exactly opposite, the leaves are so likewise.

that the upper are opposite or verticillate. If the leaves which compose each spire are very near together, and at the same time the interval between each system is well marked, the spire, becoming very short, resembles verticillate leaves, as in *Convallaria verticillata*,—or opposite ones, as in *Dioscorea*. When these leaves are sheathing, we clearly see that they are not really opposite, but that one is a little above the other, as in the glumes of the Glamineæ.

Thus, when we considered the Stem, we observed that there was a remarkable connexion between its structure and the number of cotyledons; in the same manner we may here establish a general law, that in Dicotyledons the leaves are primordially opposite or verticillate, but may become alternate or spiral in consequence of their mode of growth; and that in Monocotyledons they are primitively alternate or spiral, but may become more or less opposite or verticillate in their successive development; whence it results, consequently, that every plant which has the lower or primordial leaves alternate or in a spire, is a Monocotyledon, even when the upper ones are opposite or verticillate.

The leaves of both classes may appear to arise in bundles, and are said to be FASCICULATE, from some of the following causes:—

1st. Compound leaves may have the common petiole so short, that the leaflets seem to arise in a bundle from a common base, as in *Aspalathus*.

2d. It sometimes happens that the true leaf is either wholly or partly abortive, and at the same time the branch which is developed in its axil remains very short, and furnished with small leaves; this takes place in the Barberry, the spire of this shrub being the rudiment of its true leaf, and those which are called leaves are axillary leaflets, crowded upon a very short branch. This phenomenon takes place in certain species of *Aspalathus* and in *Pinus*, where the sheath represents the leaf, and the two, three, or five leaves which it contains are the first of an abortive branch. The Cedar and Larch show that fasciculate leaves are only those of a branch, very near together; for in the spring they are fasciculate, and when the axillary branches have had time to elongate during the summer, the leaves become alternate. The Asparagi owe to an analogous cause their bundles of axillary leaves, from the axil of a scale which is the rudiment of the true leaf.

Thus, leaves said to be fasciculate do not constitute a primitive disposition, but are combinations, of which all the systems of leaves can be susceptible.

Section VIII.

Of Stipules.

The name of Stipules *(stipulæ)* is given to little foliaceous organs, situated on both sides of the base of leaves.

Stipules do not exist in Monocotyledonous plants, or in any Dicotyledon which has a sheathing petiole; among Dicotyledons with leaves which do not sheath, they are also very frequently absent, especially in those with opposite leaves. Their existence however appears to be intimately connected with the general symmetry of plants, for they exist or are absent in all the species of a family; thus, stipules are found in the Rubiaceæ, Malvaceæ, Amentaceæ, Leguminosæ, Rosaceæ, &c.,

and they are wanting in all the Caryophylleæ, Myrtaceæ, &c.

The only thing which essentially characterises the stipules, is their lateral position at the base of leaves; for otherwise all their other characters are very variable in different plants; and it is not impossible that we might confound, under this common name, organs in reality distinct. Their texture in several plants is perfectly foliaceous, and in this case they present all the properties peculiar to leaves; so that it might be said that they are only small accessory ones, sometimes petiolate, more frequently sessile, sometimes entire, sometimes toothed or lobed, with pinnate or palmate nerves, &c.; but none are ever found to be compound, peltinerved, or pedalinerved.

They are frequently found membranous, as the leaves themselves become in several plants; and in certain respects it might be said that these stipules are the phyllodia of stipules, for they most commonly have an enlarged base and longitudinal nerves, as petioles devoid of limbs.

It appears that some stipules degenerate into true spines, by becoming indurated; such are those of *Pictetia*. But it must be observed, that the name of spiny stipules is sometimes given to different organs; thus, in several species of *Acacia*, such as *A. pilosa* and *A. hæmatomma*, we see at the same time on each side of the base of the leaves a true stipule, and a spine which is situated below it, and is evidently a prolongation of the *coussinet** of the leaf; whence we may conclude, from analogy,—1st, that what are called the stipulary spines of the Mimoseæ, are not, as is believed, hardened stipules, but

* This name is given to a little swelling of the stem, situated under the leaf, and serving as a support to it. It is particularly visible in the Leguminosæ. In Latin it is named *pulvinus*.

processes of the *coussinet;* 2d, that when the *coussinet* has a tendency thus to be prolonged into a spine, the stipules which ought to spring above it are frequently abortive.

Lastly, stipules may appear to be, like certain petioles, capable of being transformed into tendrils: it is perhaps a transformation of this kind which gives origin to the tendrils of the Cucurbitaceæ; we see in following the vegetation of *Trapa natans,* that those stipules which grow under water are elongated, and not unlike simple tendrils, whilst those which are produced in the air are flat, oblong, and resembling for the most part ordinary stipules.

The size of stipules, though less variable than their texture, also presents remarkable differences; in general they are smaller than the leaves, but there are some plants in which the stipules are developed more than the true leaves, and then they perform the physiological functions of these organs; this happens very evidently in *Lathyrus aphaca,* where the leaflets are almost always abortive, and the stipules alone elaborate the sap. The contrary takes place in several other Leguminosæ, where the stipules are so small that it may be said that they are almost completely absent, and frequently even they are absolutely abortive.

The duration of stipules is also one of the variable modifications of this organ; there are some which are persistent at the base of leaves throughout their existence, and fall off nearly at the same time with them; these are generally those of a foliaceous texture, which follow thus the lot of the leaves. There are others, principally membranous ones, which fall off very early, such are those of the Oak and most Amentaceæ; this circumstance often makes us fancy that they are wanting where they have simply dropped off early; lastly, there are some also among membranous ones, and especially spiny ones, which remain after the fall of the leaves; this is observed in several woody Rubiaceæ, in *Erythroxylon*, &c.

One of the most remarkable differences which stipules present, when compared together, is the various manners in which they adhere either to the petiole or to each other.

With regard to the first, stipules are said to be Petiolary, when by their inner side they are more or less joined to the petiole—as, for example, in *Rosa*, *Trifolium*, &c.; they are called Caulinary when they do not adhere to the petiole, as in *Vicia*. Petiolary stipules, on account of their adherence to the petiole, have in general the same duration as the leaf; caulinary ones are those alone among which we find remarkable variations of duration, that is to say, which can either fall off early or continue after the leaves.

Those which arise on both sides of the leaf are sometimes so large that they are united together at the opposite side of the stem; then the two stipules seem only to make one opposite the petiole; and as this union is rarely complete, the portions which remain free at the apex may appear as two teeth or lobes; and it is usual to say, that this pretended single stipule is emarginate, or bifid: this we see in several species of *Astralagus*, which form the sections of *A. synochreati* and *hypoglottidæi*. On comparing together the species of these two sections, we may remark all the different degrees of their junction. All stipules said to be opposite the leaves, appear to be formed in the same manner; when they do not present any emargination, we may judge of them by analogy, and by the disposition of the nerves: these stipules are found in *Magnolia*, *Ricinus*, certain species of *Ficus* (Pl. 6.) &c.

Lateral stipules may also be united together in a contrary direction, so as to become intra-axillary: this is very clearly observed in *Melianthus major* (Pl. 13, fig. 5); the great foliaceous and intra-axillary stipule which distinguishes this species is formed by the union of two, which is easily perceived, both by the disposition of the nerves and by the comparison of it with *Melianthus comosus* (Pl. 13, fig. 4), where the two stipules remain distinct and lateral. I am inclined to believe that all the stipules said to be intra-axillary come under this law; thus, those of several Rubiaceæ, *Gomphia*, Erythroxyleæ, &c., are formed by the junction of two lateral ones: there are cases where this fact is perfectly visible. Perhaps in the same manner it ought to be said that the Ochrea in the Polygoneæ is nothing but the prolongation of the base of the petiole into membranous stipules, joined together so as to form a more or less complete sheath, more or less detached from the leaf itself.

In opposite leaves provided with stipules, it frequently happens that those of each side of a leaf are united with those of the opposite leaf, whence it results that there seem to be but two stipules, one on each side common to the two leaves. Several Geraniaceæ present this peculiarity in a very evident manner; the stipules of the Rubiaceæ, with opposite leaves, belong to this class; they are sometimes united by their base alone, sometimes as far as the apex, so as to seem a single stipule.

In certain verticillate leaves, such as *Rubia*, *Galium*, &c. the buds or young branches do not spring from the axils of the leaves, but only from two opposite ones. I think that the two furnished with buds are the true leaves, and that the others ought to be considered sometimes as foliaceous stipules, (and I think that this is the case in several stellate ones,) and sometimes as the lobes of palmatisected leaves, which is perhaps the case with the seminal leaves of Firs.

It is sometimes difficult to distinguish well the lower leaflets of leaves with stipules; and this confusion is especially easy in two cases—viz. when the stipules are foliaceous, or when they adhere to the petiole; but, in either case, a little attention given to the point of origin of the stipule will remove all doubts.

One of the most striking general characters to distinguish leaves and stipules is, that the former have at their axil a bud, of which the latter are devoid: this observation makes me doubt if it be correct to say, that the two buds which are developed laterally to the axil, in the young shoots of the Willow, of which the natural bud has been removed, are those of the stipules, as Du Petit-Thouars appears to think; but whether they are not rather simple adventitious ones, such as can be produced in other places and other trees where no stipules are found.

The leaflets of compound leaves present sometimes at their base, little organs, which are to these leaflets nearly the same as stipules are to leaves. I have given to them the name of Stipels. They are general solitary at the base of the lateral leaflets, and to the number of two (one on each side) at the base of the terminal one; they are observed, for example, in most of the Hedysareæ.

The natural use of the stipules appears in general to be, to cover over and to protect the leaves during their development. This is evident in the Amentaceæ, Rosaceæ, and, in general, in plants the buds of which are wholly, or in part, formed by the stipules; but it must be confessed that in several cases their small size, their nature, or their form, renders them hardly fit for this purpose, which is the only one that can be assigned to them: those which are foliaceous cooperate in the elaboration of the juices; those which are changed into spines, serve for the defence of the plant.

SECTION IX.

Of the Union of Leaves with each other and with other Organs.

Leaves are organs which unite with the greatest facility both with one another and with the stem or peduncles.

When two leaves are found very near together at their margins, at the period of their development, they join together, as is frequently seen in purely accidental cases; thus I have figured an example of the Laurel, (Pl. 14, fig. 1,) and another of *Justicia oxyphylla*, (Pl. 14, fig. 2,) and there is no botanist who has not found analogous ones in different plants. There are plants in which this phenomenon, instead of being accidental, is more or less constant; thus, opposite leaves are very frequently united by their bases, so that they seem to form a single disk pierced by the stem; this is seen in *Crassula perfossa*, *Sylphium perfoliatum*, and in the upper leaves of several Honeysuckles (*Lonicera*). In these last, in particular, the fact is the more striking, as in following the leaves from the base upwards we can see all the degrees, from those perfectly free to those which are completely united. To these opposite leaves united at their base the name of CONNATE (*folia connata*) is given. When the leaves are verticillate they can also be united together, so as to surround the stem by a kind of ring; we see this in the floral leaves of *Seseli Hippomarathrum*, for example.

Leaves which are neither opposite nor verticillate cannot, on account of their position, be naturally united by their edges, but there happens another phenomenon analogous to the preceding:—if they are sessile, and their lower parts are sufficiently developed to allow of their making the circuit of the stem, it happens in some cases that the two edges are joined together at the base, and the limb thus surrounds the stem, which seems to pierce it. It is this which takes place in *Bupleurum perfoliatum*. We say then that the leaf is PERFOLIATE, a name which has also been extended to cases of opposite or verticillate ones, joined together; for example, *Crassula perfoliata*, *Triosteum perfoliatum*, &c.

In all these different cases the annular limb, which results from the union of several leaves or lobes of the same leaf, may present two positions: — either it is entirely spread open, and forms a ring which cuts the stem at nearly a right angle; or it is more or less erect, and then following the direction of the stem, it surrounds it by a kind of sheath, more or less prolonged. In this last case it happens sometimes that the sheath remains distinct from the stem, and does not adhere to it, as in the Gramineæ; sometimes its internal surface adheres to the stem, and seems to make part of it; it is in this manner, for example, that the leaves of *Salicornia* sheathe the stem and adhere to it.

In reference to this, some Ficoids present a very singular appearance: their leaves are opposite, very thick, and so joined together by their edges (connate) that each pair contains within it the young shoot about to be developed; when the top of the stem enlarges, it breaks the union of the leaves, which serve as a bud for it, and it appears beyond it, having in the same manner two united leaves, which enclose the following shoot.

The leaves may also be adherent to the stem, after two systems, confounded in books under the name of DECURRENT leaves: we call by this name all those the limbs of which are prolonged on both sides into foliaceous tongues, which seem to arise from the stem. This appearance may be produced by two causes:—

1st. The leaf may be adherent to the stem by the upper surface of its middle nerve, so that it seems to proceed from the stem at the place where its junction with it ceases, and the part of its limb which arises from the portion of the nerve adherent to the stem seems to proceed from the stem itself, and form two lateral wings. This takes place in the floral leaf of the Lime *(Tilia)*, and in the leaves of several species of *Solanum*.

2d. The leaf may be prolonged at its base into auricles, which are directed along the stem, and are adherent to it: this happens in most of the leaves said to be decurrent. *Prenanthes viminea* presents a very remarkable example.

Leaves can, as we have said, be united to peduncles, which thus seem to spring from the petiole or the leaf; but as this phenomenon has more importance in the history of the peduncle than in that of the leaf, we shall speak of it when we treat of the Inflorescence.

There are cases where the distinction between leaves and peduncles, which appears clear and easy in general, becomes extremely complicated; this happens in the Ferns. I have purposely omitted mentioning them in this chapter on Leaves, for the organs called leaves may indifferently be considered either as true leaves, which bear the flowers and fruit, or as peduncles, bordered by foliaceous wings; under this doubt I shall delay treating of them until I speak of the fructification of this family.

Section X.

Of the Irregularity of foliaceous Organs.

The ordinary state of leaves is symmetrical; that is to say, that, in general, the two sides of the leaf separated by the middle nerve have a tendency to be equal and alike. This tendency to symmetry is remarked both in simple and compound leaves, and it is generally observed likewise in each lobe or leaflet considered separately; but to form an exact idea of this symmetry, we must not seek for a too geometrical regularity, which never exists in organized beings. The two sides of leaves are considered as symmetrical or regular when they differ but little in the same dimensions, or when they do so in a variable and accidental manner. But there is a certain number of plants in which the two sides of the leaves, or leaflets, are constantly unequal, and they are designated by the names of Inequilateral or Oblique. Thus, in leaves, the two sides of those of *Begonia* are very remarkable for their inequality; several species of *Grewia* present analogous examples; it is also visible in *Pterospermum semisagittatum*, &c. This inequality generally exists only in alternate leaves, and I cannot find in my memoranda any example of an inequilateral opposite leaf. This fact tends to prove that this inequality ought to be referred to the position of the leaf upon the plant favouring the development of one of its sides more than the other; and in this case it is always the lower which is developed most.

This law is still more evident in the leaflets of pinnate leaves: when they are unequal, which frequently is the case, and are met with indifferently in alternate or opposite leaflets, the side most developed is always the lower, the upper being narrower and less prolonged.

In leaves with palmate, peltate, or pedate nerves, when there is inequality in the two sides of the leaflets, or lobes, the external are always those which are developed most, probably because their development is not restrained by the neighbouring parts. The same observation may be made upon the stipules, which are very frequently irregular, the outer side, or that most distant from the petiole, having a tendency to be dilated much more than the inner, whence it results that several of them have the longitudinal nerve very near the inner edge, and their general form is semiovate, semicordate, or semisagittate.

The inequality of the two sides of a compound leaf is also perceptible in certain leaves, in some of the sides being devoid of a leaflet, the existence of which is indicated by the general symmetry; thus, *Anthyllis tetraphylla*, and all the species of *Anthyllis* of the section of Cornicineæ, are devoid of a leaflet or a stipule towards the base of one of the sides of the leaf. Thus, in several species of *Mimosa* (Pl. 13, figs. 2, 2*,) the common petiole of which bears two partial ones, each of which wants a leaflet of the lower pair of the inner side, this absence is owing to a constant abortion, for the place of the leaflet is vacant, and in some accidental cases it is developed.

Not only have leaves, considered with regard to themselves, their sides symmetrical, but they also almost always present a symmetry in size, when they are considered with regard to their position upon the stem. Thus, in almost all opposite or verticillate leaves, those which spring from the same horizontal plane are perceptibly equal. Sometimes, in verticillate ones, they are alternately a little unequal; but in opposite ones there has recently been presented a curious example of inequality in *Ruellia anisophylla*:—one of two opposite leaves is very small and narrow, and, as it were, abortive in comparison with the other; but symmetry is also met with in this irregularity, for on comparing the successive pairs, the small leaf is found alternately on both sides.

Stipules present analogous phenomena; thus it happens, although rarely, that those of the two sides of a leaf are unequal in form and size. This is very remarkable in *Ervum Ervilia*, in which one of the stipules of each leaf is small, entire, scarcely apparent, whilst the other is large and cut. There are some plants where they do not seem to exist on one side: such are the stipulary tendrils of several Cucurbitaceæ, supposing that these are true stipules; such are especially the stipulary spines of some Capparideæ, such as *Capparis heteracantha*, &c.

Section XI.

Of the History of Leaves at different Periods of their Existence.

The leaves arise upon the young shoots, and all of them are already existing there, and more or less developed, at the moment when this young shoot begins to appear; necessarily they are very close to each other, very small, and reduced, thus to speak, to their fibrous skeleton. At this period sometimes the outer leaves, altered in their development by the action of the air, take the appearance of scales, and serve as coverings to the inner leaves, and to the young shoot itself; sometimes, on the contrary, they are developed as the inner ones, and do not appear so clearly to serve for their envelope: in the former case the name of Scaly Bud is given to the integument formed by the outer leaves, and in the latter we say that the leaves are naked, or without buds. The buds being organs common to the nutritive and reproductive parts, and only being formed by the degeneration of other organs, their detailed study will only be presented to us in the Fourth Book of this work, but we have to examine here the state of leaves from the period of their birth to that of their death; it must also be remarked, that we will consider their history with regard to their structure, properly so called, and not as regards their physiological functions.

Leaves, whether considered as enclosed in a bud, or developed naked at their birth, are always, at this age, disposed in such a manner as to occupy the least possible space. Different causes determine their appearance at this period, viz. their position and mode of adherence to the stem, the disposition of their principal nerves, and the different degrees of separation or union of their parts. All the appearances which result from the complication of these causes may be reduced to a limited number of folds, or curves, under which all known leaves may be classed. Under this head, leaves are—1st, folded or rolled lengthways upon the longitudinal nerve, which remains straight; 2d, folded or curved, so that their apex is applied to their base; 3d, they present sometimes neither curves nor perceptible folds.

The most usual state of the leaves, or portions of the leaves, of Dicotyledons, and especially of those with petioles which do not sheath, is to be folded lengthways upon their middle nerve, so that the two sides of the limb have a tendency to be applied one upon the other by their upper surface. This appears to be the normal state of all leaves and leaflets with pinnate nerves, but the appearance is modified by very slight differences. Thus, for example, when two penninerved leaves are exactly opposite, and in crossing pairs, they are so folded as to embrace the inner pair: we see this in the Privet. These kinds of leaves are said to be EQUITATIVE. When the opposite position of leaves is less exact, one of the sides of each leaf is found a little on the outside, and the other, consequently, a little on the inside: this happens in *Saponaria*, and then the leaves are said to be SEMI-EMBRACING. When the leaves are alternate or quincunx, each is folded wholly upon itself, and, thus folded, they are found lying side by side without embracing each other: this is the case in the Beech; they are then said to be CONDUPLICATE.

Palminerved leaves may be considered, as we have seen above, as formed by the junction of partial penninerved limbs, each of which has a tendency to be folded upon itself, and it results that the whole of the limb is folded upon the nerves like a fan; this takes place in the Vine and all palminerved leaves. They are said to be PLICATE, or folded in a fan-like manner.

The leaflets of palmate leaves present the same disposition: they are folded upon their middle nerve, and placed side by side; those of pinnate ones are also folded and placed in like manner, covering each other on the edges of a common petiole.

Some penninerved leaves present peculiarities which, without differing much from the general rule, have caused them to have particular names. Thus, there are some, which, although folded upon the middle nerve, have their two edges more or less rolled, either outwards, as in the Rosemary, and are said to be REVOLUTE; or inwards, as in *Euonymus*, or *Nymphæa*, which are said to be INVOLUTE; or upon one another, as in the Apricot, when they are termed SUPERVOLUTE. It is not known what is the peculiarity of structure in these plants which causes this disposition to roll up, so rare in Dicotyledons, but so common in Monocotyledons.

Lastly, there are some leaves of Dicotyledons, which, although provided with a middle nerve, are so narrow, that they cannot be folded, and lie over one another without any apparent order; this takes place in the Larch, Fir, &c.: they are termed Imbricate. Petioles without limbs present an analogous disposition when they are not sheathing.

Leaves with the petiole embracing the stem for a considerable extent (this comprehends most Monocotyledons, and some Dicotyledons), present in their infancy dispositions slightly differing from the preceding. Most of them, which are only composed of a dilated petiole, are simply curved and imbricated upon one another; we see this in the coats of the Onion, in the leaves of most Liliaceæ, and in the sheaths devoid of limbs, which form the upper leaves of the Umbelliferæ, or the involucra of the Compositæ. Those sheathes, which are very narrow, are almost flat; and the larger they are, the more are they curved.

There are some plants with sheathing petioles, in which this organ has a tendency to fold back lengthways upon itself, as if it had a middle nerve, and thus takes the appearance of a vertical limb formed by the application of the two sides of their upper surface: this happens in the Iris. Considered in their infancy, these leaves are said to be Embracing, because, being alternate, each of them embraces by its two borders the two borders of the leaf which follows it. Considered as to their form at the state of complete development, they are named, as I have said above, Ensiform. Among Monocotyledons with a sheathing petiole, we find several intermediate states between those leaves with a curved or folded petiole; thus, the petioles of the Potamogetons approach in this respect those of the Iris; the leaves of several Hyacinths are nearly folded lengthways, &c.

A third disposition, entirely peculiar to Monocotyledons provided with limbs, is that of being CONVOLUTE; that is to say, of having the limb rolled in the form of a cone upon one of its edges which proceeds from the axis; it is this which is found in the Scitamineæ and Amomeæ.

Almost all the leaves of plants enter into one of the dispositions which I have mentioned; but there are some which seem formed upon an entirely different type, and instead of being folded in a longitudinal direction, are so in a transverse one. Such are—

1st. Leaves said to be REPLICATE; that is to say, those which are folded so that their upper part is applied to the lower; this is observed in the leaves of *Aconitum*. The young leaves of the Tulip-tree *(Liriodendron tulipifera)* have the petiole curved, so that the limb is folded back upon the base, and may be considered as belonging to this class.

2d. CIRCINNATE Leaves: that is to say, those which are rolled up from the apex to the base, the point of the leaf, or of each of its lobes, serving as the axis of the roll. This takes place in Dicotyledons in the Droseraceæ, in Monocotyledons in the Cycadeæ, and is found in the highest degree in the Ferns.

As soon as leaves begin to grow, they are seen to elongate and enlarge very regularly; but the laws of this growth are not as well known as could be desired.

Petioles formed of parallel fibres, and of a foliaceous appearance, as those of Monocotyledons, and particularly the foliaceous organs, which, for the sake of abbreviation, are called leaves in Hyacinths and other bulbous plants, elongate in a manner peculiar to them—viz.

their apex is the first part which appears, and they are elevated in issuing from the bulb as if they were pushed up from below. Upon a leaf of this kind, half developed, I marked points at equal distances; these marks remained at the same distance at which I placed them, but the lowest was found further from the base from the development of the part situated below it, and before buried in the bulb; thus, while the branches of the year elongate throughout their whole length, and the roots by their extremities alone, these kinds of leaves or petioles do so by their base.

Is it the same with ordinary petioles, and nerves, which are only the divisions of petioles? This is what I am inclined to believe, but I cannot as yet affirm it, for want of conclusive experiments.

The growth in breadth is essentially owing to the elongation of the lateral fibres in all plants with ramifying or diverging nerves, and to the development of the intermediate parenchyma. As for the enlargement of those with parallel or conveying nerves, it is generally slight, and only appears to be owing to the development of intermediate cellular tissue; it is also remarked that the breadth of leaves is much less subject to variations in these than in the preceding.

The growth of leaves, both in length and breadth, attains its limit generally very rapidly; then the leaf performs its functions for some time, and enjoys the plenitude of its existence; but by degrees, from its exhaling perfectly pure, and, as it were, distilled water, and retaining in its tissue earthy matter which the sap has carried there, the vessels harden, and the exhaling pores are obstructed: this term arrives generally the more rapidly as the evaporation is more active. We see the leaves of herbaceous plants, or of trees which evaporate much, fall off before the end of the year which has seen them produced; whilst those of succulent plants, or of trees of a hard and coriaceous texture, both of which, although from different causes, evaporate but little, often remain for several years. It may be said in general then, that the duration of the life of leaves is in inverse ratio to the activity of their evaporation. When this period arrives, the leaf dries up by degrees, and finally perishes; but the death of the leaf must not be confounded with its fall: these are two phenomena which, although frequently connected, are entirely different. All leaves die at a certain period, but some are gradually destroyed by external causes, without falling off; and others fall off, being detached from the stem at their base.

At the time when the death and fall of leaves were confounded, Mustel thought that this fall was caused by the state of fulness which leaves acquired at the end of their life; but this state, which may be considered as a cause of death, is not of itself a cause of their fall.

M. Vrolyck has sought to establish, that when the leaf is dead, the living part of the tree tends to cast it off, as the living parts of animals throw off dead parts, as is seen in the phenomena of Gangrene and Necrosis; but this explanation, ingenious as it is, goes too far, since there is a number of leaves which die without being detached from the stem which bears them.

Sénebier began to distinguish the death from the fall, and attributed the latter to the growth of the bud of the following year, which in the summer is developed in the axils of leaves. I do not deny that the growth of this bud may facilitate the fall, but it cannot be the essential cause of it; for—1st. There are leaves, and especially stipules, which have no buds in their axil, and which fall as others. 2d. There are leaflets which have no buds, and which become detached from a common petiole, when particular causes, such as the sting of an insect, affect them. 3d. Lastly, there are other organs which have no buds at their base, and which fall off in a manner so analogous to leaves, that it is impossible to believe that facts so similar should be caused by causes entirely different.

Duhamel came near the cause of the phenomenon when he compared the fall of leaves to the disease of the Vine, in which the upper joints of the young shoots are disarticulated when they are affected by early frosts, or only, perhaps, by cold and damp seasons. The fall of leaves resembles this phenomenon in its being a true disarticulation, but it differs in this, being a constant and regular fact, which takes place at the same period, whatever the external circumstances may be.

Vaucher has, in fact, established, that leaves which are continuous with the stem die without falling off, but that all those which are articulated with it necessarily drop at a certain period of their existence. The leaflets of compound leaves, being articulated in the same manner with a common petiole, may, therefore, fall off independently of the leaf. Thus the fall of leaves, like that of fruits, is determined beforehand, and is a necessary consequence of the assistance of an articulation.

It is true to say only that it is facilitated by different causes; such are the growth of the bud in the axil of the petiole; the cessation or diminution of vegetation, which tends to dry up and twist the petiole; the growth of the trunk, which tends to disunite the fibres of the base of the leaf; the action of atmospheric inclemencies, such as frost, cold moisture, and especially hoar-frost, which tend to diminish vegetation; the actions of mechanical agents, such as the wind, hail, or rain, which tend to shake the base of leaves. All these different causes explain the slight anomalies which the leaves of trees present at the period of their fall; but the real cause of this fall is always the existence of an articulation.

Leaves are in general called CADUCOUS, when they fall off at the end of the first year, and PERSISTENT when they last longer: we designate in particular by the name of EVERGREEN trees, those which have persistent leaves. But it must be remarked, that these terms, deduced from appearance, are far from being correct: leaves destined to fall off ought to be called FALLING leaves, and among these we may distinguish:—1st. Those which fall off the first year, or ANNUAL ones;—2d. Those which fall off the second year, after the development of new leaves, or BIENNIAL ones;—3d. There are some falling leaves, as those of Firs, which remain two, three, or a greater number of years, but which ought not to be confounded with persistent leaves, although both constitute the permanent foliage of evergreen trees and shrubs.

SECTION XII.

Of the Functions of Leaves, and of the means of supplying their place in Leafless Plants.

The functions of leaves are objects more physiological than anatomical, and which we ought only to examine in a summary manner.

1st. We have seen that all the structure of this organ has for its result the isolation of the extremities of the sap-vessels, leaving, however, cellular tissue between each of them. The open extremities of the vessels or intercellular passages, or the stomata, serve in general for the aqueous evaporation : this is the first or principal function of leaves. This aqueous exhalation is the more active, the greater the number of leaves, the larger their surface, and the more stomata they have in a given space.

2d. A consequence of this first point, which may be considered a second use of leaves, is that of causing the ascent of the sap; for the quantity of water drawn up by a plant under given circumstances, is in general perceptibly proportional to the extent of leaves which the plant bears; and when different species are compared, to the total number of stomata.

3d. There are circumstances in which the stomata, instead of exhaling the super-abundant water, appear to absorb that which is externally in contact with them; it is thus that withered leaves absorb the water with which they are sprinkled; and it is thus also that Charles Bonnet made branches to live by placing that part of their leaves which was provided with stomata, upon a watery surface.

4th. Leaves exposed to the action of light in an atmosphere which contains a small quantity of carbonic acid gas, or in water which holds in solution air mixed with carbonic acid, decompose this gas, exhale the oxygen, and appear to fix the carbon.

5th. When they are exposed to the air during the night, they absorb a certain quantity of oxygen, which is as much as seven times their volume for trees with annual leaves, but which is gradually less for herbs, trees with persistent leaves, marsh and succulent plants. It is probable that this absorption of oxygen, discovered by Theodore de Saussure, contributes to facilitate the decomposition of the substances contained in the sap.

6th. It results from the different facts mentioned above, that the principal elaboration of the sap is performed in the leaves, and that these are the organs in particular which form the Cambium, or the juice which nourishes and develops the wood and bark. This important use of leaves may be recognised in the experiments when the leaves of a branch are in part or entirely removed, when we see its growth diminish in proportion throughout all the part below that where the leaves were taken off. From the preceding circumstances, we may conclude how idle are the discussions so freuqently introduced into physiological and agricultural works, to know if the leaves nourish the plant more or less than the roots; it is just as if it were to be asked whether a man's lungs nourished him more or less than his stomach. Nutrition is a phenomenon perfected and performed by several organs. The roots contribute their part, and the leaves theirs.

7th. Leaves, in presenting to the winds two resisting surfaces, more or less considerable, tend to produce an almost continual agitation in the branches of trees; and we know, from some beautiful experiments of Mr. Knight, that the motion of the branches facilitates the progress of the sap and the growth of the trunk; it is, perhaps, one of the causes which makes trees with large leaves to grow more rapidly.

8th. A great number of leaves also serve for the secretion of different particular juices, according to the nature of the glands with which they are provided.

9th. Several serve for the particular shelter and protection either of the flowers or fruit, or of the buds situated in their axils.

These different functions are so important that the leaves constitute the truly active portion of vegetation; and it is difficult to understand how it is possible for plants to exist devoid of these essential organs. This, however, happens under different forms, and we shall here briefly examine the means by which the use of leaves is supplied, wholly or in part, when they happen to be wanting either naturally or accidentally.

When the leaves are accidentally wanting at the period when their presence is necessary, as, for example, if for any particular purpose they are stripped off a tree when it is in a growing state, as is done to the Mulberry; or if the hail destroy all of them, when the tree is in full growth; a vital phenomenon ensues, which partly repairs the injury. All the latent buds in the axils, which would not have been developed till the following year, grow very rapidly, and form new leaves; if, by any particular circumstance, this phenomenon does not take place, the tree usually perishes.

Plants deprived of leaves by their own organization, deserve to be examined more in detail, as it refers entirely to Organography. It may be said, in general, that when a plant is naturally devoid of leaves, the use of these organs is supplied by some other organ of the same plant, or by another plant.

The absence or diminution of the limb is supplied:—

1st. By the dilatation of the petiole, the fibres of which spread out and separate sufficiently to permit the development of cellular tissue and the opening of stomata; this is observed in the highest degree in almost all leaves without limbs.

2d. The foliaceous limb is also supplied sometimes by the stipules, which are the more developed the more completely the limb is devoid of leaflets, as is seen in *Lathyrus Aphaca.*

3d. In several plants in which the leaves are either totally wanting, or are very small, or fall off very early, the surface of the bark of the young branches, which, in the ordinary state, is a parenchyma, very analogous to that of leaves, performs entirely the function of those organs; its cellular envelope is more developed than usual, and the number of stomata is greater; this is observed in the young branches of *Ephedra, Stapelia, Ceropegia, Cactus,* the fleshy species of *Euphorbium, Xylophylla, Casuarina, Equisetum,* and in general of all plants not parasitical and devoid of leaves. All these branches, physiologically speaking, enjoy the function of leaves, and often take their appearance and form. One of the errors which must be guarded against in the study of these plants, is, that the name of leaves has been for a long time given to true branches; thus, the oval discs of *Opuntia* are compressed branches, since they bear leaves, and after some years become true cylindrical trunks: the true leaves of these plants are the little conical or oblong bodies which are situated below the clusters of spiny hairs, and which fall off very early.

4th. There exist some plants, the bark of which is not transformed into foliaceous surfaces, and is devoid of true leaves, or has them deduced to the state of scales, deprived of stomata, and incapable of physiological action; but most of these plants, and perhaps all of them, are parasites; that is to say, they are endowed with the faculty of implanting themselves upon plants furnished with leaves, and of appropriating the sap elaborated by them.

Thus some, such as *Cuscuta,* attach themselves to the branches of other plants, from which they absorb nourishment by means of their suckers: *Cassytha* appears to live in the same manner.

Others, such as *Orobanche,* grow upon the roots of other plants, from which they draw an important part of their nourishment: they are attached to the roots by only some of their radicules, a great number of others being free. These latter appear to extract from the soil a certain quantity of sap; but it appears, however, that, at least in the young state of the plant, it is absolutely necessary that the *Orobanche* should be attached to a plant provided with leaves. It is most probable that *Lathræa*, *Monotropa* *Orchis abortiva*, and *Limodorum epipogium*, are nourished in an analogous manner; but the nutrition of these singular plants has been but little studied, and it is desirable that their history should be followed in detail and with accuracy by some botanist accustomed to physiological observations.

CHAPTER IV.

OF THE NUTRITIVE ORGANS OF CELLULAR PLANTS.

Section I.

General Considerations.

After having described the numberless variations, but which are subject to general rules, which the nutritive organs of vascular plants present, it is necessary to speak of the organs which correspond to them in cellular plants. Here we shall find as much similarity in the inner parts as we have remarked differences in vascular plants, and the external forms are here in proportion more varied than in the large plants.

Cellular plants have not, as we have already mentioned, either vessels, properly so called, or stomata: the former appear to be replaced, as regards their office, and often their appearance, by bundles of elongated cellules; and the latter probably are so by imperceptible pores. The entire mass of these plants seems composed of one and the same substance, which takes different forms, and performs various functions, without being able to be divided into distinct organs. It is in this point of view that several authors have thought that we cannot apply to cellular plants the same names which are used for the organs of vascular ones; thus, for example, Wildenow designated by the name of *Cormus* every part of these plants which is above ground; but this term does not appear to me to be correct, since certain cellular plants, as the Truffle, live entirely under ground, and have no organ exactly resembling that which would bear the name of Cormus in the Lycoperdons. Persoon, Acharius, and Lamouroux, less perceived the homogeneity of the nutritive parts of these plants, when they designated by a common and single name every part which did not serve for the reproduction; Persoon named it *Peridium* in the Fungi, Acharius *Thallus* in Lichens, and Lamouroux *Frons* in the Algæ. The first of these terms makes too much allusion to the character of an envelope, which this organ frequently performs; the last signifies too clearly that it is foliaceous, which is not always the case. I am inclined, then, to admit generically the name of THALLUS to designate the mass of nutritive organs of cellular plants; or at least of all the Algæ, Fungi, Lichens, and those Hepaticæ in which distinct organs cannot be distinguished.

Most naturalists, neglecting on the contrary this fundamental idea of the homogeneous nature of the parts of cellular plants, have perpetually described them as composed of parts analogous to those of vascular ones; but the vagueness of these descriptions is manifested in each sentence, and all those terms ought to be taken rather for simple metaphors than expressions of the reality: thus, when the body of a cellular plant is almost cylindrical and erect, the name of stem has been given to it, and its ramifications have borne that of branches; when this same body is flat and membraneous it has been named a leaf. This desire to refer the forms of cellular plants to the terms used for vascular ones has caused much confusion in the writings of Cryptogamic botanists. In order that the degree of homogeneity of structure, and the difference in the general forms which are presented in cellular plants, may be perceived at once, I shall rapidly give a description of the nutritive organs in each family of this class. This course appears to me the only one which can be followed in the actual state of the science; for we are so ill acquainted with each of these families, that it seems to me impossible to make any general remarks, worthy of confidence, upon the whole of the class.

Section II.

Of Mosses.

The Mosses are those, of all cellular plants, which have the greatest affinity to vascular ones, and they also differ but very little, as to their appearance, from the Lycopodiums, with which they have sometimes been confounded. The great difference which separates them, with regard to the organs of vegetation, is purely negative; it is that the tracheæ, the different orders of vessels, and the stomata, are absent in Mosses; the existence of tracheæ and other vessels is not admitted by any observer, but some have thought that they have perceived stomata in the capsule of *Splachnum*. I have, I confess, some doubt upon this observation, which I have not been able to verify; but at least, it remains certain that stomata are absent from all the nutritive organs of Mosses. The stem, nerves, and the parts in general, which in other plants present vessels only, here offer bundles of elongated cellules, which replace the vessels in appearance, and probably also in use. The stem of Mosses is generally cylindrical; and when it appears compressed, as in *Hypnum Schreberi*, or tetragonal, as in *Bryum tetragonum*, it is owing to the disposition of the leaves. The stems are sometimes very long, as in *Polytricha* and *Hypnum;* sometimes very short, as in several kinds of *Weissia;* sometimes so short that they almost escape notice, and are only represented by a kind of little bulb, from which spring the floral organs, as, for example, in several species of *Phascum*, *Buxbaumia*, &c. These differences of size are analogous to what we have above remarked, (Chap. I. Sect. I.) on comparing the stems of *Dracæna*, for example, with the bulbs of Liliaceæ.

The stem of Mosses is sometimes frequently simple, as in *Webera pyriformis*, and then the plant is almost always annual. When it is branched, either by producing young shoots at its base, or emitting lateral or terminal branches, each of these shoots denotes generally the growth of a year, and it is in this sense that Hedwig has given them the name of *Innovationes*. But the peculiar mode of growth of Mosses and of their ramifications has been but little studied. It appears that the elongation of the stem or branch of a year is caused by an extension which takes place principally at the upper part, and which stops at a fixed period in each species, nearly as in the branches of Dicotyledons: there must be the formation of a new shoot for the stem to elongate again. We can easily perceive these different shoots in the old stems of *Polytricha*. As to the growth in diameter, it appears to me to take place only at the first period of development: these stems perceptibly retain the same diameter throughout their whole length, and almost at all ages.

The roots of Mosses are generally fine filaments, of a brown colour, more or less branched, which spring either from the base of the stem, as in PHASCUM, and which are called PRIMARY ROOTS, because they are developed at the origin of the plant; or along the stem, and then they are named SECONDARY ROOTS, because they are developed after the first, during the whole life of the plant: they have been seen to issue from the leaves. They are especially frequent in most Mosses which live in turfy ground; it is not rare to find in the Mosses of these localities, which are perennial, all the lower part of the stem abundantly covered with a brown tissue, formed of an innumerable multitude of roots. But no one, to my knowledge, has yet carefully studied either the structure or mode of absorption of these organs. Mosses which live on rocks seem entirely devoid of them, and, as they can draw nothing from the rock itself, it is likely that their first radicules are introduced into the imperceptible fissures, and thus serve to fix the young plant, but that, afterwards, it is nourished by the absorption of its leaves rather than by that of its roots. This mode of absorption, which is found in all Mosses, combined with the dry and half-dead appearance which their roots very quickly acquire, causes me to think that these organs do not influence the absorption, except in their infancy, and afterwards remain around the stems of those growing in turfy places, as if to serve for their protection against wet.

The leaves arise along the stem, sometimes joined together at their base, sometimes collected into rosettes, or terminal buds, at others, alternate or spiral, along the stems, shoots, and branches: they are almost always sessile and sheathing at the base. They have the form of little scales, oval or elongated, rarely obtuse, but almost always pointed or acuminate, sometimes prolonged into a long cilia, or, as it were, rolled into a cirrhiform point. *Bryum macrocarpum* presents this singular appearance, the leaf being entire and prolonged into a branching cilia. Their colour is of a beautiful green, but sometimes they are naturally scaly, or transparent at the apex; some are devoid of all nerves, and formed entirely of homogeneous, nearly round, cellular tissue; others present near the middle a nerve of variable length, which sometimes reaches the apex, sometimes stops in the middle, and sometimes is only visible at the base. These differences are observed in species elsewhere very similar, and demonstrate the slight anatomical importance of these nerves; they are, in fact, only formed of elongated cellules, which, by uniting together, resemble the nerves of vascular leaves.

All the leaves of Mosses are continuous with the stem, and never fall off of themselves; they remain a long time dried at the base of the stems of those in dry situations, but in those of damp places they are destroyed by maceration, and then, if they have no nerve, or only a very weak one, the stem becomes naked; if, on the contrary, the nerve is strong, it remains under the form of a hair, or small spine, after the maceration of the surrounding parenchyma; this is observed in *Fontinalis*, and the aquatic species of *Hypnum*, &c.

The ordinary leaves of Mosses have the margin sometimes entire, at others serrated; sometimes these teeth are so fine and numerous that the leaf appears ciliated;

but no full-grown leaf is ever divided. This structure is only met with in the primordial or radical ones of a small number of Mosses, such as *Phascum cohærens;* these leaves are irregularly divided into slender processes, composed of cellules placed end to end, the partitions of which are visible with a lens.

The absorption of water is performed by Mosses with singular facility, and when one which has been dried for a long time is plunged in, it regains the freshness and appearance of life. Some have even asserted that, like the Rotiferæ, dry and dead plants may be restored to life by being placed in water; but this important fact does not appear to have been sufficiently demonstrated. When only half of a dried Moss is dipped into water, the submerged part acquires the appearance of life, and the other continues dry; this fact, of which we shall find numerous examples in the following families, tends to show that the effects of absorption in cellular plants are much more local than in vascular ones. Finally, there is no doubt that, in the ordinary state of their vegetation, they absorb much water by their foliaceous surface; it is probable that this is their principal means of nutrition; that their life is preserved for a long time in a state of torpor, and can be reanimated by rain or immersion: this frequently happens to perennial ones, which only grow well in a moist season, and appear dried up in summer. Whence comes this faculty? it is the subject of doubt above mentioned.

Leaves, which perform, as we have seen, so important a function in these plants, are hardly ever absent. *Buxbaumia aphylla* alone appears entirely devoid of them, and its vegetation is a peculiar mystery, at least in its infancy.

I have already described the ordinary structure of the leaves of Mosses; but there happens in some species of this family an important deviation from their usual state; they are sometimes disposed in two rows, and instead of embracing the stem at their base, they are prolonged by one of their sides upon it. This is seen in several species of *Fissidens*, to which, from this appearance, the names of *pennatum*, *adianthoïdes*, &c. are given. These seem, in fact, the leaflets or segments of a pinnate leaf, disposed on both sides of a common petiole, and one would be inclined to believe this, if the extremity of the stem were not often prolonged into a branch or flower. The illusion goes sometimes even farther, for there happen cases when the neigbouring leaves are partly united together by their sides, and then, if the stem do not flower, it seems a pinnatifid leaf. We may form an idea of this phenomenon by examining *Gymnostomum pennatum*, and almost all the species of *Fissidens*. We will revert to its importance on speaking of the Hepaticæ.

The leaves of Mosses are also sometimes capable of joining together; they then present two points at their apex, and if they are furnished with nerves, they have two throughout their length. This is accidentally observed in *Gymnostomum truncatum;* it is possible that it may be an analogous phenomenon which causes, in some species, a double or bifid nerve, as in *Neckera Hypnoïdes*, &c.

Let us observe, lastly, in order to complete what relates to the structure of the nutritive organs of Mosses, that their leaves differ from those of all vascular plants in their cellules, being disposed upon the same plane, so that two distinct layers cannot be distinguished, and they cannot be separated into two parts. This character is still more decided in those *Hepaticæ* which have leaves, and it tends to prove, as I have indicated in the first Section of this Chapter, that what is called a leaf in these plants differs much from ordinary ones, and that those organs are only expansions of the stem, and entirely of the same nature.

Section III.

Of the Hepaticæ.

The structure of the Hepaticæ is very similar to that of Mosses, as regards the organs of nutrition; but it presents some peculiarities which deserve to be mentioned here with more care, since they tend to make us understand the general organization of cellular plants. Let us first commence with those Hepaticæ which most resemble Mosses, in order to arrive at those which approach the Lichens; for this family, although very natural and not numerous, is a true group of transition.

The Jungermanniæ, or at least the greatest number of this genus, present such analogies to the Mosses, that old botanists joined them together. They present, in the same manner, a cylindrical stem, simple or branched; roots, primary and secondary ones, sometimes springing from the leaves, and most frequently along the stem; and, lastly, sessile leaves, sheathing at the base, persistent, scattered or distichous along the stem: all these organs are, as in Mosses, composed of cellular tissue, without any appearance either of stomata, tracheæ, or vessels. But the differences which may be observed between the Jungermanniæ and true Mosses are — 1st. That the leaves of the former are constantly devoid of nerves, and entirely composed of round cellular tissue. 2d. That they are more seldom entire, often dentated, and differently divided or cut, especially at their apex, so as to present more varied forms; sometimes they are all divided into minute filaments, formed of cellules in a simple row, and very much resembling the primordial leaves of *Phascum*. 3d. At the base of the true leaves of the Jungermanniæ are often found foliaceous appendages, sometimes joined by the side to the leaf, sometimes distinct from it. These appendages, which are absent in Mosses and several Hepaticæ, have been named STIPULES, from a vague analogy to the stipules of Dicotyledons; they only differ from true leaves in their being smaller, and often disposed in a slightly different manner; they are, properly speaking, accessory leaves.

If now we examine those Jungermanniæ which are nearest allied to Mosses, we shall find some which, analogous to *Fissidens*, have the leaves disposed in two rows, scarcely, if at all, sheathing, and prolonged by the side upon the stem; such are *Jungermannia sphærocarpa* and *J. capitata;* and then the stem, when it does not bear flowers, resembles a petiole furnished with segments. Let us go farther on, and we shall find species where these leaves are united together upon the two sides of the stem, so as to form there a kind of foliaceous limb, sometimes dentated or interrupted when the leaves are incompletely united, and sometimes continuous when they are so completely.

When this phenomenon takes place in plants provided with stipules, these are found in their usual place, and form kinds of foliaceous scales along the stem, or, to speak according to appearances, along the middle of the leaf, formed by the union of the true leaves with the stem: we see this in *Jungermannia Lyellii.* In these different cases the stem is visible, and represented by the middle of the foliaceous organ, which forms the whole of the plant: sometimes it happens that it is scarcely distinct from the rest of the tissue, and then the plant presents the appearance of a foliaceous expansion, lying on the ground, and shooting out roots or cramps; thus, following the forms of *Jungermannia epiphylla*, afterwards of *J. pinguis*, we arrive by almost imperceptible transitions to *Anthoceros*, *Marchantia*, and *Riccia*, in which we perceive nothing more than a foliaceous disc, representing at the same time the stem and leaves, emitting from one side roots and from the other the organs of reproduction; it is this foliaceous organ, which is neither stem nor leaves, or at the same time both one and the other, which has been named the FRONS.

Thus, the history of the Hepaticæ tends to show, that if for reasons of convenience and apparent analogy, there have been described in these plants stems and leaves, these organs are far from being distinct, as in vascular plants, and that the mass of cellular ones, in appearance the most compound, presents also a great homogeneity.

SECTION IV.

Of Lichens.

The Lichens are still more remarkable than the Hepaticæ, by the union of these two circumstances, in appearance contradictory—the prodigious variety of form in different species, and the homogeneity of the tissue of each. Among Lichens, some present plane expansions, green, of a foliaceous appearance, and very analogous to the structure of *Riccia* and *Anthoceros*; as *Lobaria*, &c. Others have their whole substance gelatinous, and thus approach the Algæ and Tremellæ. There are others, and a great number, which have the form of cylindrical stems, more or less branched, sometimes even being furnished with small flat expansions, of a foliaceous appearance. Lastly, all these different forms are, in several species, reduced to dimensions so small that the whole of the plant (with the exception of the organs of fructification) is only formed of a crust, composed either of foliaceous scales, as in *Squammaria* and *Patellaria*, or of small stems very close together, as in *Isidium*, or of a granulated or pulverulent matter, which may be considered as a mass of indistinct scales, or imperceptible trunks, as takes place in *Lepra* and *Coniocarpon*. In the midst of all these variations, the internal substance only presents a mass of cellular tissue, with round or elongated cellules, usually very small, and close to one another. The most remarkable physiological character of this tissue is, that when it is torn, the internal substance becomes green on exposure to the air or light. This phenomenon is especially very remarkable in the species which adhere to rocks.

In general, the tissue of Lichens is formed of elongated cellules in the parts which resemble stems or branches, and of round ones in those which are like foliaceous expansions.

The surface presents remarkable differences: sometimes it is entirely smooth, at others it is provided with hairs or ciliæ of various kinds; at times it is prolonged into cramps, or roots, which serve to fix the plant, and perhaps to absorb nutriment. It is especially in the genus *Psora*, that these appendages appear to be true roots implanted into the soil, and serve at the same time to fix and nourish the plant. In most of the species which grow upon rocks, or trees, there are neither cramps nor roots, and the plant is fastened on the surface which bears it, by means of a little disc at its base; this adheres to rocks in a very intimate manner, and seems as if it were an incrustation. I think that an exudation of the base of the Lichen dissolves a little of the stone, and so combines with it as to cause this kind of union: it is also in the same manner, I presume, that certain Lichens sink into calcareous stones, as they advance in age, as, for example, *Verrucaria rupestris*, &c.

The Thalli of Lichens are sometimes alike throughout their whole surface. This happens when they are upright, and equally exposed on all sides to the air and light; they then have most particularly the appearance of a cylindrical stem, as in *Usnea*, *Cladonia*, &c., or compressed, as in *Physcia*, and certain species of *Rocella*. At other times the two surfaces are dissimilar. This happens in those that are in the form of leaves or scales, and in a horizontal situation; the upper surface, being exposed to the action of the air and light, is firmer, harder, and more coloured, and acts, thus to speak, the part of bark; the lower is softer, more tender, and paler, and most frequently bears hairs or cramps: it is by this surface also that the absorption of water most usually takes place. This fluid penetrates the whole of the Thallus, when a part of it is plunged in, and in many cases its trace may be followed by means of the absorption of coloured liquids.

One of the circumstances, which, according to M. Fries, appears most powerfully to modify the vegetation of Lichens, is, that it is very frequently interrupted by atmospheric changes, being suspended during drought, and regaining its activity during damp seasons.

It results from these frequent interruptions, that their life may be much prolonged, and one frequently finds in the same plant parts which appear dead, and others which continue to vegetate. When the vegetation is renewed under circumstances very different from those in which the life of the individual commenced, it may become developed in a manner very different from what it was at first, and this explains the existence of those specimens, so different in various parts of the Thallus, which have been produced at different periods of vegetation. These examples tend to prove that some Lichens, which might be thought to be of a different species, or even genus, are, in reality, only different states of the same species.

These interruptions of the life of Lichens, is connected with their longevity, which appears much greater than would be expected in plants so insignificant; thus, Vaucher observed after forty-five years the same indidual of *Lobaria pulmonaria* attached to the same place on the same tree.

The colour of individual plants frequently varies, according to the degree of atmospheric moisture; it usually becomes green when the tissue is very wet, and coloured white, green, black, yellow, or orange-red, when it is dry. I have remarked, that all those Lichens which are green, or are capable of becoming so under water, disengage oxygen gas when exposed to the solar rays; whilst this phenomenon does not take place in the species which are not green, nor capable of becoming so under water.

Section V.

Of Fungi.

Fungi, considered in that point of view in which we are here occupied, only present cellules, sometimes round, at others elongated under the form of hollow filaments, which seem to be fibres; sometimes very close together, so as to form a compact body; at others, more or less separated, almost always disposed in a mass, without any apparent order. These singular plants never present either stomata, or vessels of any kind; their entire substance is composed only of a homogeneous mass, in which it is impossible to distinguish the parts of the higher orders of plants. But some, who have wished to adopt this kind of comparison, making allusion to their colour and general appearance, have compared Fungi to the roots of plants; others, struck with the caulescent form of some, have given them the name of stems; whilst some, from the appearance of the species of *Uredo*, have compared them with the pollen of phanerogamous plants; and others, perplexed by the form of *Erineum*, have likened them to the hairs of ordinary plants.

The texture of Fungi is very variable; either soft, or very hard; fleshy, gelatinous, or coriaceous; but never presenting the usual dry state of the Lichens, nor the herbaceous softness of the Algæ. Their colour also varies much, and sometimes even presents very vivid tints; but it is never green; or, at least, if any greenish tints are perceived, they appear to result from an entirely different principle than the ordinary greenness of leaves. No Fungus lives in water; * almost all grow exposed to the air; some under ground, or buried in other living plants; although some grow in darkness, light appears necessary for their complete development.

The part of the Fungus which does not serve for the reproduction (and which is called either the THALLUS, as in Lichens, or the CORMUS, PERIDIUM, or STROMA) appears to be less developed when the fructiferous organs are more so; thus in *Uredo* and *Puccinia*, the whole

* *Peziza aquatica* appear to grow in the air, and to be covered over by the water during its growth.

plant appears to be reduced to the fructiferous organs; in *Agaricus*, *Boletus*, &c. the reproductive part only occupies a fixed portion of the plant, and the part which serves for the nutrition is much more visible. The absorption takes place at a certain point which serves for the base: this base sometimes produces radical fibrils, either buried in the earth, or spreading out on the surface; at other times it is simply fixed to the earth or rotten wood, adhering by imperceptible hairs, or by intimate juxta-position. In several species of rapid growth we can cause coloured water to penetrate the plant, and there we can see that it passes on from the base, and follows the elongated cellules, or intercellular passages.

When first developed, Fungi proceed from a kind of closed membranous integument which envelopes them, and is called the VEIL. They are always round, whatever form they may afterwards take. Their mode of development has not yet been carefully studied; in several, such as *Agaricus*, the upper part, which is named the HAT, appears to be developed before the lower, which has been compared to a stem, or peduncle; the reverse seems to take place in *Clavaria*, which appears to grow from the base upwards. Several Fungi, with horizontal expansions, surround in their development inert bodies which they meet with; the growing mass is arrested in its development by the slightest obstacle, and reunites beyond it with the greatest facility, since its homogeneity is complete: we also frequently see these plants united together.

The softer parts of Fungi are very liable to form gaps or spaces by the rupture of the cellules, as in vascular plants; thus it is that several kinds of *Agaricus* and *Boletus* have the pedicel full in their infancy, and hollow at an advanced age.

The external part is frequently distinct from the rest of the tissue, and can be separated like a skin or bark with little or no tearing; it frequently bears true hairs or scales produced by the fragments of pellicles partly detached.

As to the general forms of Fungi, the little that I can say is so intimately connected with the reproductive organs, that I must refer the reader to the following Book.

Section VI.

Of the Algæ.

Of all the families of the class Cellulares, there is none where the general character can be more easily comprehended than these; the usual transparency of their tissue renders their observation very easy, and their constantly living in water allows them to be observed under the microscope in their natural state.

The Algæ are expansions, sometimes filiform, at others foliaceous; sometimes a mixture of these two states, but of an absolutely homogeneous nature: their surface never presents stomata, and as it exhales oxygen by the action of light in the same manner as other plants, we must conclude that these organs do not serve for that purpose. The tissue of the Algæ is entirely formed of closed cellules, sometimes round, constituting the foliaceous limbs,—at others more or less elongated, forming the appearance of stems, roots, or nerves. Several of them present, in the interior of their tissue, spaces or air cavities; these are very visible in *Chara*.

The homogeneity of their nature has been remarked by all who have studied them, and the names of Frons and Thallus have been given to the mass of which they are composed: it is only by abbreviation that sometimes, in the descriptions of Fuci, stems, leaves, or roots, are spoken of, to designate portions of the thallus which have these different appearances.

Proofs of this homogeneity are often found on observing their manner of living: all parts of the thallus of Algæ appear almost equally endowed with nutritive faculties; they all absorb the water which is in contact with them, exhale oxygen, but appear to live in an almost independent manner, and only transmit the juices to the rest of the tissue with difficulty, or perhaps not at all. Thus, when a *Fucus* or *Ulva* is found only half sunk in water, the submerged part is fresh, but the other withers and dries up,—a remarkable phenomenon, which may result either from the plant not transmitting juices from one part to the other, or from the evaporation being too active in the portion exposed to the air for the others to supply it.

The thallus presents very distinct degrees of texture, which have served Lamouroux and Fries as the basis of their classification; some, as the Fucaceæ, are coriaceous, and of an olive colour; others, as the Florideæ, are cartilaginous, and more or less rose-coloured. There are some entirely membranous, as the Ulvaceæ; and gelatinous or semi-gelatinous, as the Batrachospermeæ.

The Algæ are almost all of them,* at least in their infancy, fixed upon the solid parts which form the bottom and edges of waters. Sometimes they are

* According to Vaucher, *Zygnema* and *Hydrodyction* are free in their infancy.

attached, as *Fucus vesiculosus,* by a small part of the base which adheres to solid bodies, but we know not by what kind of mechanism this takes place. Sometimes they lay hold of projecting and angular parts by kinds of root-like cramps, as *Fucus saccharinus :* this organization especially takes place in the large species, which are liable to be detached by the shock of the waves of the sea ; but these cramps do not perform, as to the absorption of juices, any function which is not common to the whole of the tissue.

The foliaceous parts are often traversed by nerves resembling in appearance those of ordinary leaves, being frequently pinnate as they are, but they are only composed of elongated cellular tissue. They are commonly also entirely devoid of nerves, as in *Ulva.* There are some which seem to be only composed of isolated cellules full of juice ; such is, in particular, *Protococcus nivalis,* or that singular production, of a red colour, which grows on the snow at the Pole, and on the Alps.

They are frequently composed, like most plants of their class, of a great number of cellules, which form a thick tissue. We can even distinguish in the Florideæ and several Fucaceæ a kind of bark, formed of round cellular tissue, distinct from the centre, which is of a tissue either elongated, or more compact, and having the appearance of a woody body. Sometimes the cellules are all disposed in a single series, whence results sometimes a foliaceous lamina, very thin, and truly membraniform, as that of the Ulvæ ; sometimes very slender filaments, all formed of cellules placed end to end, as in certain Confervæ.

The Confervæ have often been spoken of in botanical works as formed of *articulated filaments ;* it is necessary to remark here that this name is not correct, and it ought to be replaced by that of *divided filaments.* There is not, in fact, in these plants, any solution of continuity, but they present kinds of transverse partitions, produced by different causes; thus—1st, if the filament be formed of a simple series of cellules, perhaps enclosed in a membranous sheath, the partitions which divide them are visible to the eye on account of the transparency of the tissue, forming what are falsely called articulations. 2d. It happens in some species that several cellules of the same length are placed side by side, and the union of their ends, seen collectively, produces the same appearances. 3d. I have also seen pretended articulated filaments which were composed of cellules, alternately very long and very short; the latter, when slightly magnified, resembled partitions. It would be easy to multiply these examples, but they are sufficient to show that these filaments are not really articulated, and that their appearances are owing to very different causes.

The genus *Hydrodyction* is very remarkable in its anatomical structure; it presents a purse-like sac, composed of pentagonal meshes: at a certain age, the five little filaments, which by their union form a mesh, disunite, and each of them becomes a sac similar to that of which it formed a part, and is composed in the same manner, of pentagonal meshes. This example tends to confirm the opinion of those who think that the cellular tissue is developed by the swelling of the granules contained in its interior.

The Algæ evidently appear to be the vegetable family the structure of which approaches nearest to that of animals. Several genera have forms so singular that they can only be classed in one or the other kingdom for physiological reasons, and not on account of their organographical characters. Thus, the Oscillatorias and Zygnemas hardly differ in their form and manner of living: the former, which present traces of a movement probably spontaneous, are placed in the animal kingdom; whilst the latter, in which no movements are observed, are considered to be vegetables.

Among these doubtful genera, we must mention *Nostos, Diatoma,* and in general all the Diatomeæ of Fries, which are usually classed among vegetables; and the Sponges, which are referred to animals: in these and several other analogous examples, the limits of the two kingdoms are very difficult to be established.

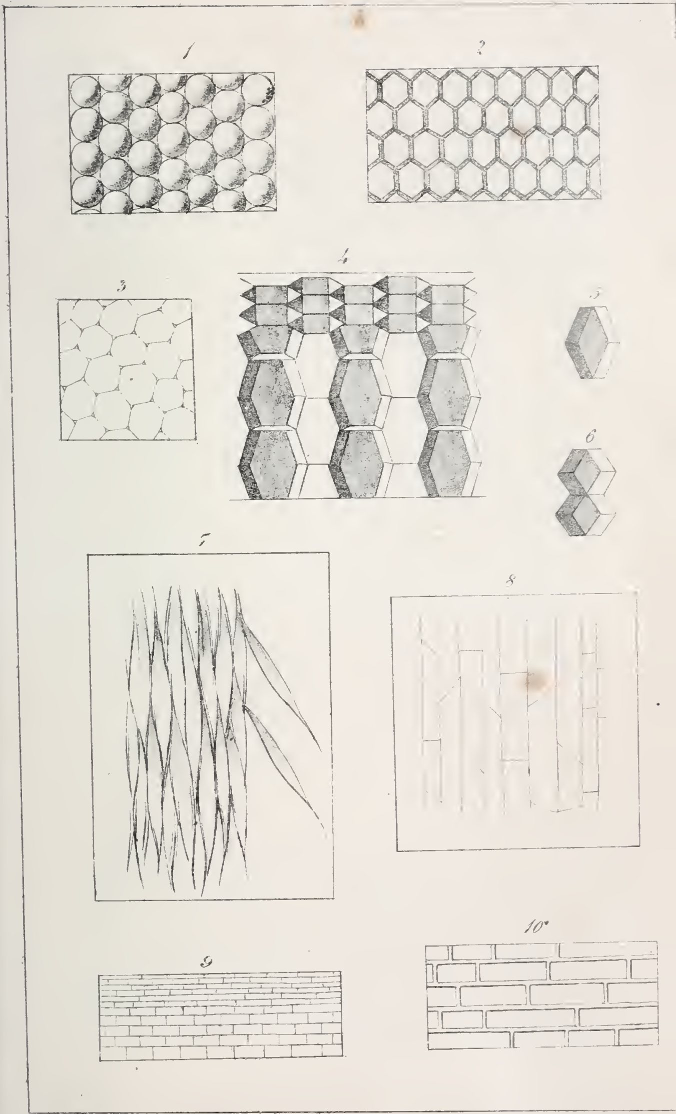
END OF VOL. I.

RICHARD CLAY, PRINTER, BREAD STREET HILL, LONDON.

ERRATA.

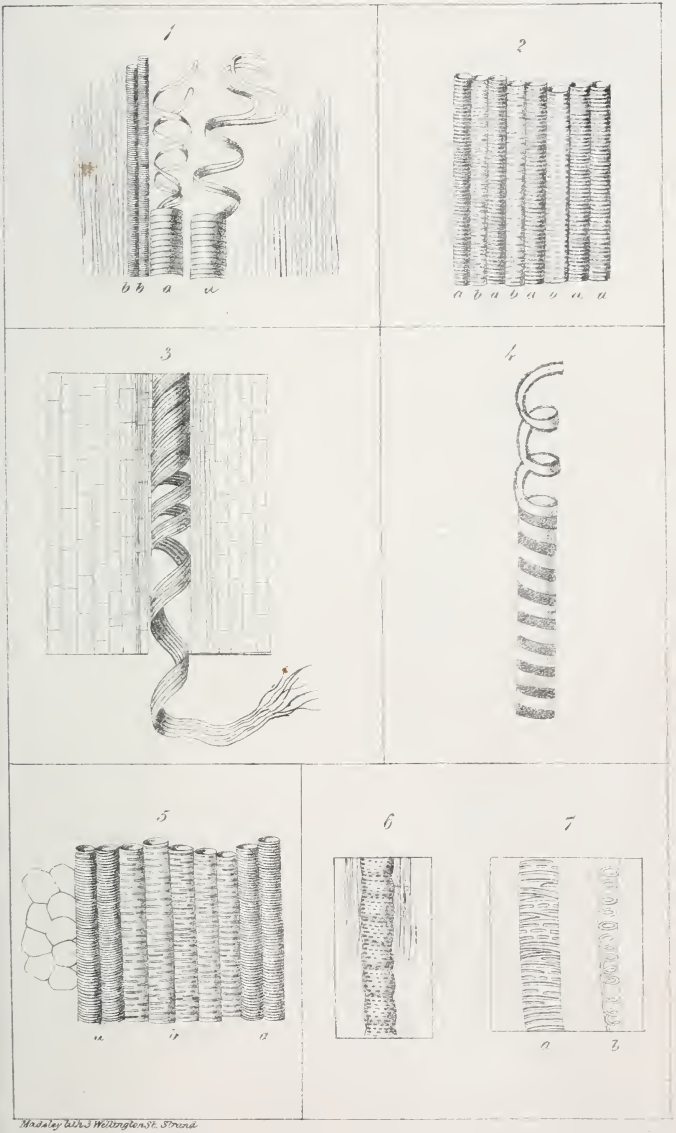
Page 246, line 24, *for Epidendrum read Epidendron.*
281, line 9, *for* Glamineæ *read* Gramineæ.

Pl. 1.



Madeley lith. 3 Wellington St Strand.

Pl. 2.



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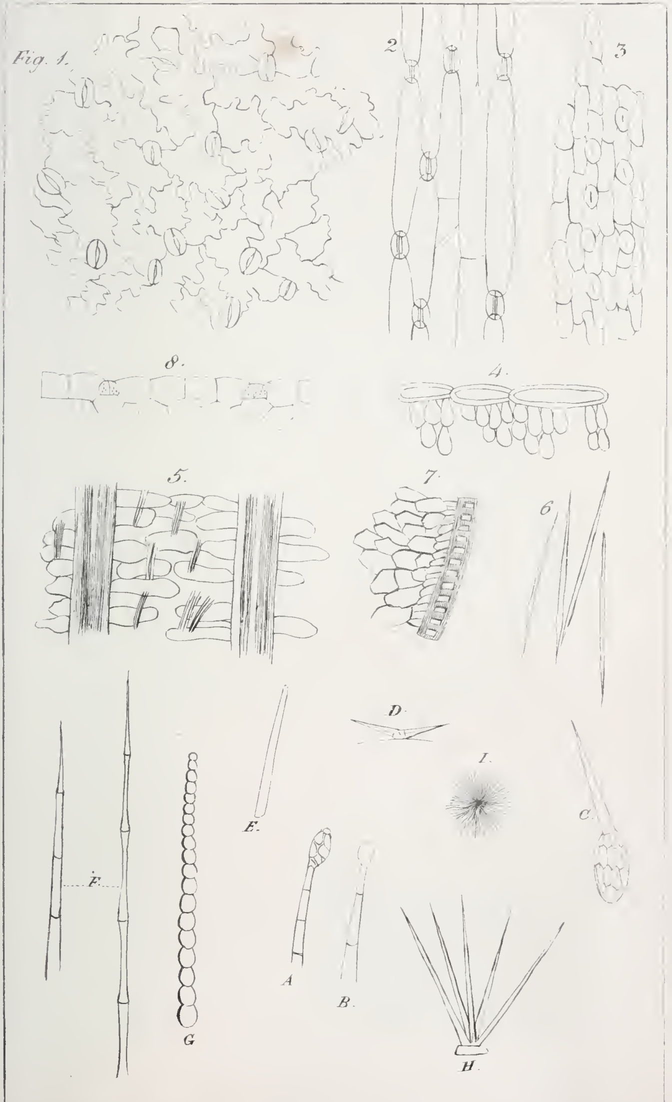

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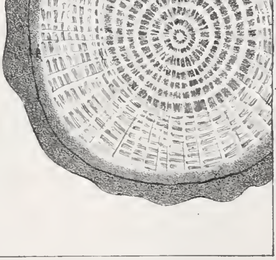

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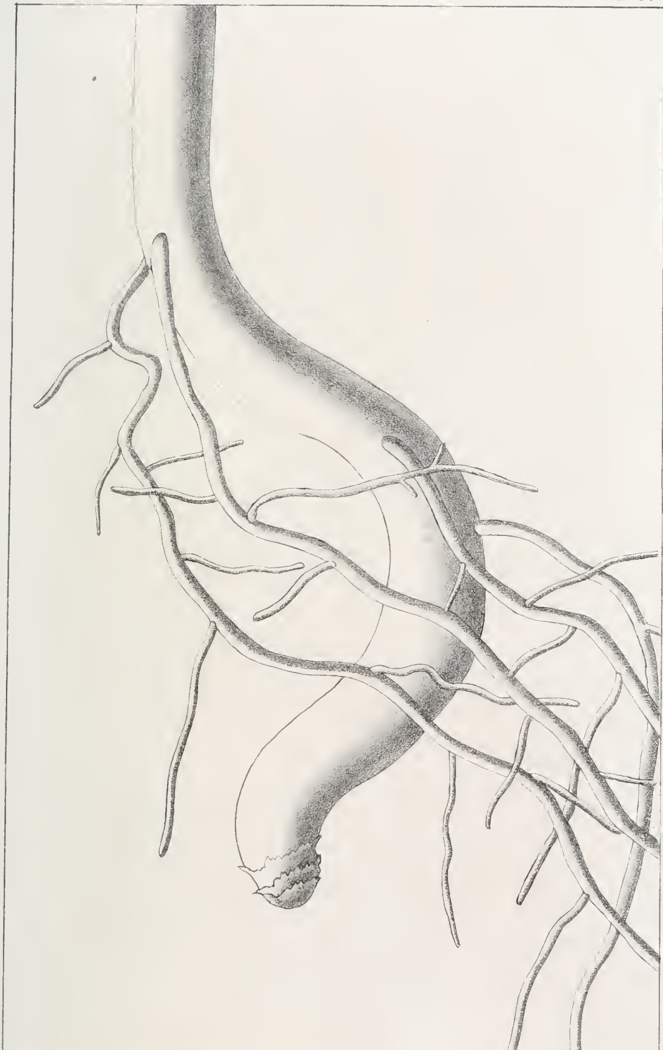

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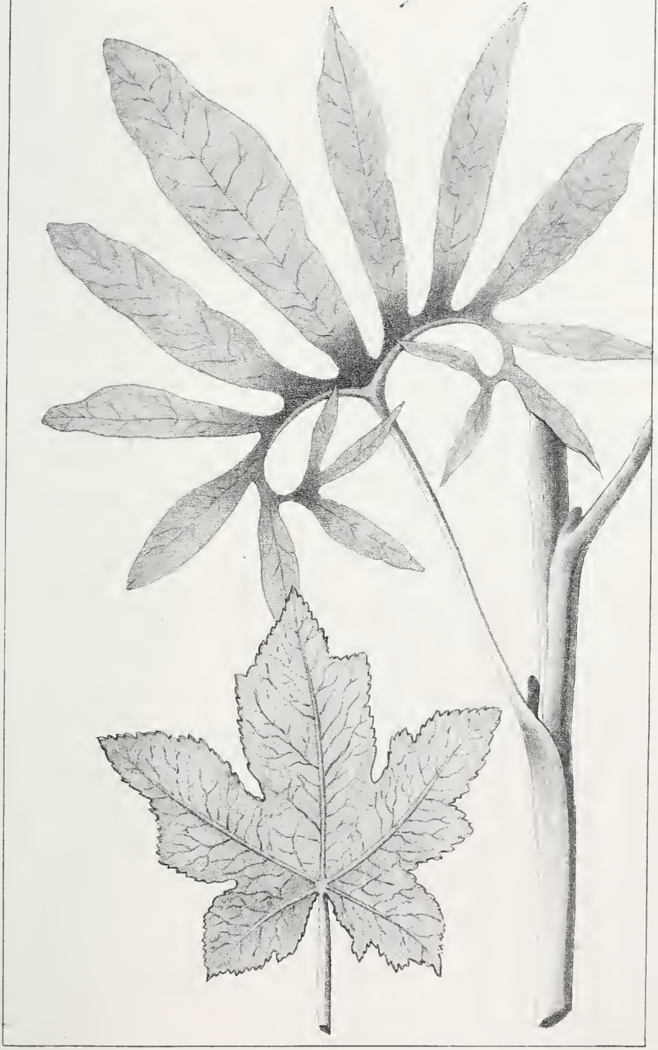

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Pl. II.

Fig. 1.

Fig. 2.

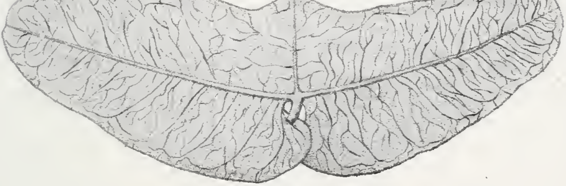

Fig. 3.

Madeley lith 3 Wellington St. Strand.

Madeley lith. 3 Wellington St. Strand.

Pl. 13.

Madeley lith. 3, Wellington St. Strand

Pl. 14.


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